Galileo's Startling Look Into Jupiter

ASTRONOMY®

New Planets!

April 1996 U.S. $3.95
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ICD 08070

See Bright Meteors This Month

Observing Galaxies on Edge

MEADE
7" LX200
8" LX200
10" LX200
12" LX200
7" LX50
8" LX50
10" LX50
4" ED/APO
5" ED/APO
Starfinder Equatorial 6"
8"
10"
6" ED/APO
7" ED/APO
16"
Starfinder Dobsonian 6"
8"
10"
12.5"
16"
MEADE
STARFINDER MEADE

Price Increase Announcement

A general increase of 8% to 17% in the prices of almost all models of Meade astronomical telescopes will take place on May 1, 1996.

Over the past five years the Meade Instruments factory in Irvine, California, has been continuously updated into one of the most modern, most efficient facilities in the world for the manufacture of precision astronomical instrumentation. This utilization of the very latest in high-technology equipment—in Meade optical fabrication and coating rooms, in the machining department, in telescope testing and quality assurance, and in instrument assembly—has enabled us to maintain stable pricing levels for the great majority of the more than two dozen astronomical telescope models that we manufacture. In some cases prices for Meade telescopes have not increased in more than three years, despite numerous technical improvements that have been put in place on every model during that period.

We believe that Meade LX200's, LX50's, ED/APO's, and Starfinder Equatorials and Dobsonians represent the very best in American technology—a fact confirmed every day by the large numbers of Meade telescopes that we export around the world. In spite of the formidable pricing competition that we face in many foreign countries, Meade astronomical telescopes have attained a predominant position in virtually every country.

Notwithstanding the success that Meade Instruments has achieved, a success for which we are profoundly grateful to amateur astronomers in the United States and worldwide, even Meade technology and manufacturing efficiency have their limits. It is for these reasons that the prices of Meade astronomical telescopes must undergo a general price increase.

We are making this advance announcement of the May 1, 1996, price increase in order to offer a final opportunity for our customers to purchase a Meade telescope at current prices. Even at their new prices, listed below, Meade telescopes will still represent, by far, the finest values available in quality astronomical instrumentation.

Price increase announcements, however uncommon they may be at Meade Instruments, normally result in a substantial increase in our manufacturing backlog. We therefore urge an early purchase of the Meade model you are considering, to avoid a long waiting period.

Meade Telescope Model	*Current Price through April 30, 1996*	*New Price effective May 1, 1996*
8" LX200 Schmidt-Cassegrain	$2495	$2795
10" LX200 Schmidt-Cassegrain	2895	3195
12" LX200 Schmidt-Cassegrain	3995	4495
7" LX200 Maksutov-Cassegrain	2995	3295
8" LX50 Schmidt-Cassegrain	1195	1395
10" LX50 Schmidt-Cassegrain	1495	1695
7" LX50 Maksutov-Cassegrain	1595	1795
4" ED Apochromatic Refractor	2495	2795
5" ED Apochromatic Refractor	2995	3295
6" ED Apochromatic Refractor	4495	4995
7" ED Apochromatic Refractor	5495	5995
Starfinder Equatorial 6	599.95	649.95
Starfinder Equatorial 8	699.95	749.95
Starfinder Equatorial 10	799.95	879.95
Starfinder Equatorial 16	2495	2695
Starfinder Dobsonian 6	325	349
Starfinder Dobsonian 8	425	469
Starfinder Dobsonian 10	595	649
Starfinder Dobsonian 12.5	795	895
Starfinder Dobsonian 16	1095	1195

Prices shown are suggested U.S. national mail-order retail prices, exclusive of any applicable sales taxes or credit card charges, and do not include packing and shipping. Specifications for Meade telescope models are listed in advertisements elsewhere in this magazine issue, or contact your authorized Meade Advanced Products dealer for complete information. The 76-page Meade 1996 General Catalog is available directly from Meade Instruments at $3.00, forwarded by first class mail.

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World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur

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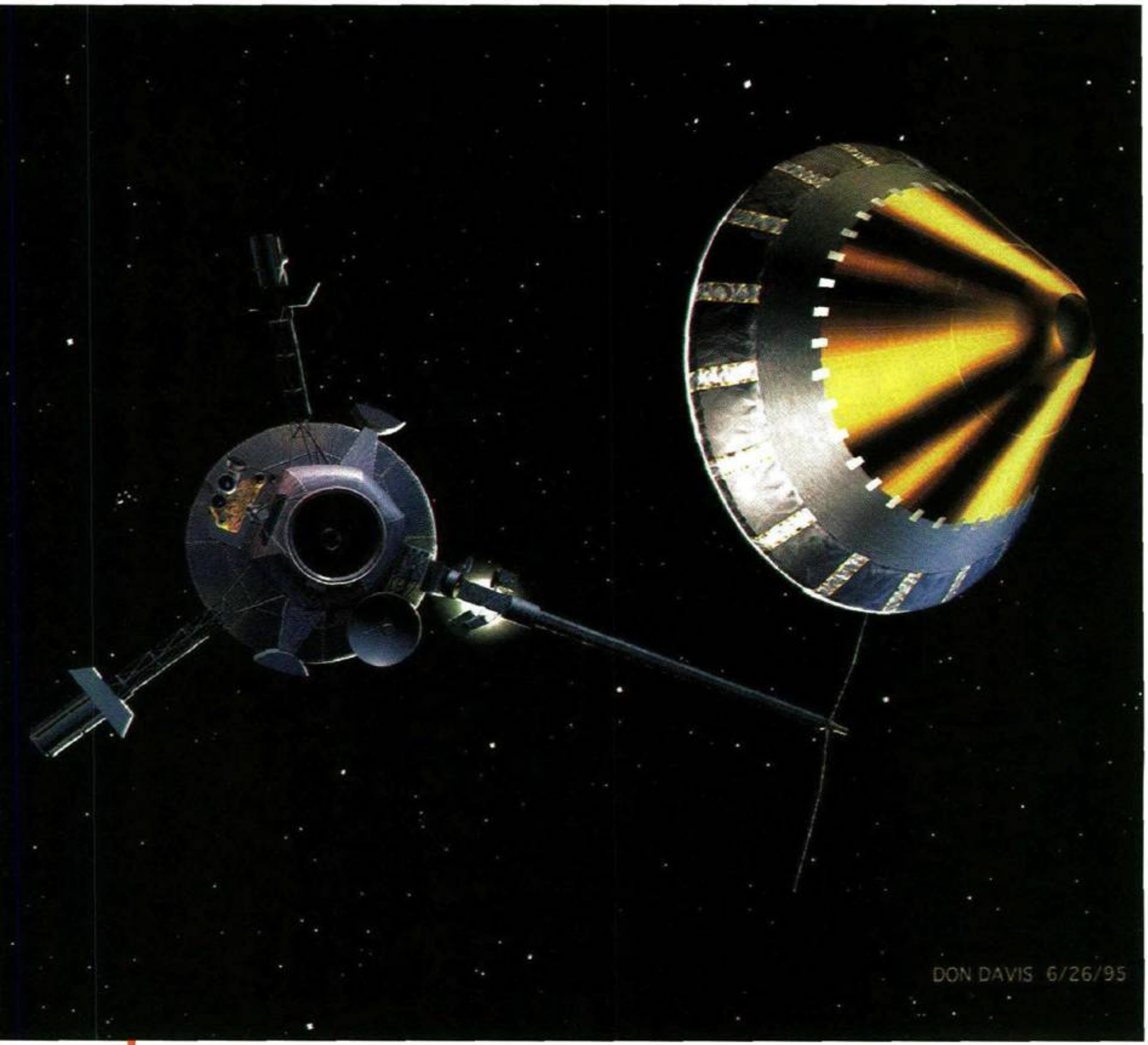
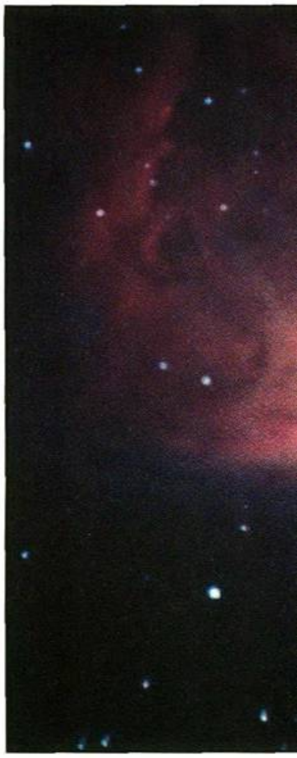
April 1996
Vol. 24, No. 4



NASA/Don Davis

42 Galileo's Startling Look into Jupiter



Jack Marling

34 The Day the Dinosaurs Died
Untold numbers of species perished after an asteroid smashed Earth 65 million years ago. Here's what happened that fateful day. By Ron Cowen.

42 Into the Maelstrom
The Galileo probe has changed our view of Jupiter forever. By Robert Burnham.

46 To the Edge of Space and Time
Hubble peers deep to capture galaxies as they formed. By Robert Naeye.

COVER 50 Two New Solar Systems
Astronomers discover two more Jupiter-sized planets orbiting Sun-like stars. By Robert Naeye.

56 Sky Almanac
Watch the Moon disappear into Earth's shadow during April's early evening eclipse. By Deborah Byrd and Rick Shaffer.

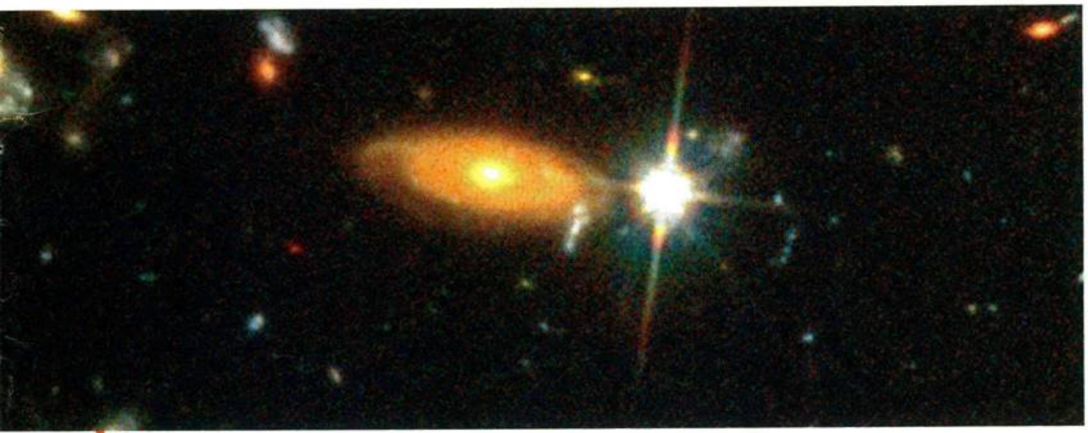
ON THE COVER

JUPITER'S GIANT COUSIN looms above a hypothetical moon as they orbit the Sun-like star 70 Virginis. For more on this new planet, and another found circling 47 Ursae Majoris, see page 50. Painting by Michael Carroll.

78 Hypercharge Your Astrofilm

34 The Day the Dinosaurs Died

Ron Miller



Robert Williams (STScI) and NASA

46 To the Edge of Space and Time

66 Galaxies on Edge

Take your springtime observing to new extremes with a modest-sized scope by spying the thin disks of edge-on spirals. By Ronald W. Kohl.

72 An April Shower

The Lyrid meteor shower won't bring May flowers, but with no Moon the night sky will bloom with incinerating comet debris. By Philip M. Bagnall.

74 An Exotic Eclipse

Shadow chasers returned from Asia with stunning photos. By Jeff Kanipe.

78 Hypercharge Your Astrofilm

Hypering turns slow, fine-grained film into a super performer. By John Shibley.

82 A Window into the Deep

With a large telescope, you can scan across 500 million light-years to see the rich and varied Hercules Cluster of galaxies . By Tom Johnston.

DEPARTMENTS

6 Behind the Scenes
- Mystery Planets, Round 2

6 Letters

18 AstroForum
- The Hourglass

22 AstroNews
- Not-So-Naked Quasars
- A Planet at Beta Pictoris?
- Sea-Ice Ridges on Jupiter's Moon Europa
- Putting the Sun in Its Place
- Multiple Impact on Earth by Asteroid or Comet String?
- Next Stop, Comet Wild 2

30 Amateur News
- CCDs Front and Center
- The Other Star Party in Texas

84 Astronomy Books
- A Hubble Double Dip

90 AstroBytes
- Planetary Observing Made Easy

94 New Products
- Economically Priced Binoculars
- Batteryless Red Flashlight
- Binocular Mount
- Solar Eclipse Poster

98 Resources and Photofacts

98 Meetings and Events

104 Advertiser Index

105 Reader Reports
- Night of the Leonids

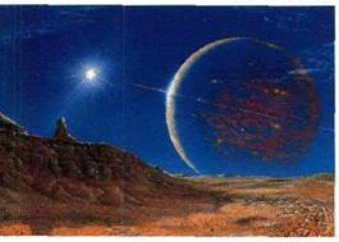
110 Ultimate Exposure

BEHIND THE SCENES

Mystery Planets, Round 2

Here we go again. Last month, you may recall, we ran a feature story on the new planetary system belonging to the star 51 Pegasi. Then, as we were preparing to put this issue to bed, along came the startling discovery of two more systems, each with at least one mystery planet of its own.

With the widespread attention given to these discoveries, we set aside one already completed story — don't worry, you'll see it soon in an upcoming issue — so that Associate Editor Bob Naeye could leap into the breach (just as he did last month) and write the news feature you'll find on page 50.


Michael Carroll

New world of the month: 70 Virginis B

And that's not all. If you could look at the front half of the April issue we started planning months ago, you'd find that only Ron Cowen's story on "The Day the Dinosaurs Died" actually made it into print. The other three stories all grew out of late-breaking news. Besides the one on the new planetary systems, you'll find stories on the dramatic Hubble Space Telescope photo of galaxies reaching into deep space — how many astrophotographers ever take exposures lasting 10 *days*? — and the first science results from the Galileo probe mission into Jupiter's stormy atmosphere.

To me, the most wonderful thing about all these discoveries is that there could be even *more* planetary systems known by the time you read this. Over and over, astronomers find that once you know how to look for something, one discovery leads directly to another.

For all the havoc this creates as we cozy up to deadline, discovery is astronomy's life-blood. It doesn't really matter whether you're a professional astronomer at an observatory control desk or a backyard observer aiming a telescope into a starlit sky. All of us hunger for discoveries as we seek new understandings of the universe.

Because that's what being human is all about.

Sincerely,

Robert Burnham

Robert Burnham
Editor
rburnham@astronomy.com

LETTERS

Art or Photography?

Since the beginnings of photography a debate has occurred in the background: Are images from cameras art or mere photography? Now, in an ironic twist, I browse the pages of astronomical magazines and ask: Are some of the enhanced images I see photography, or mere art?

Since California astrophotographers Tony and Daphne Hallas revealed their image enhancement techniques in 1989, skyshooters have been one-upping each other by adding contrast and color saturation to finished images. Darkroom technology placed a limit of sorts on this race. However, with more astrophotographers enhancing images digitally, there's no limit to the processing you can do. So the question arises: How much *should* be done?

Jerry Lodriguss, a photographer who scans his images into a com-

[continued on page 14]

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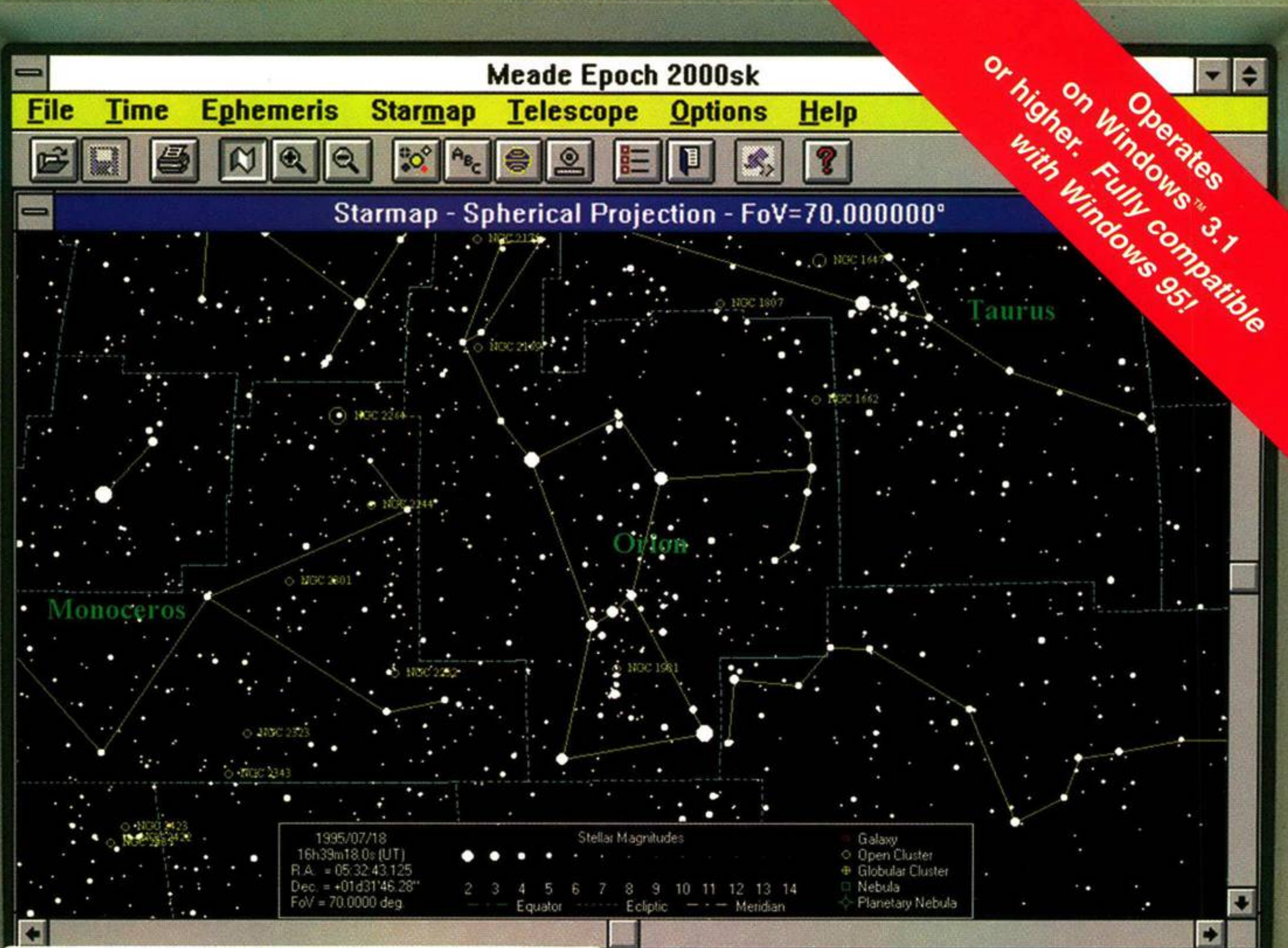
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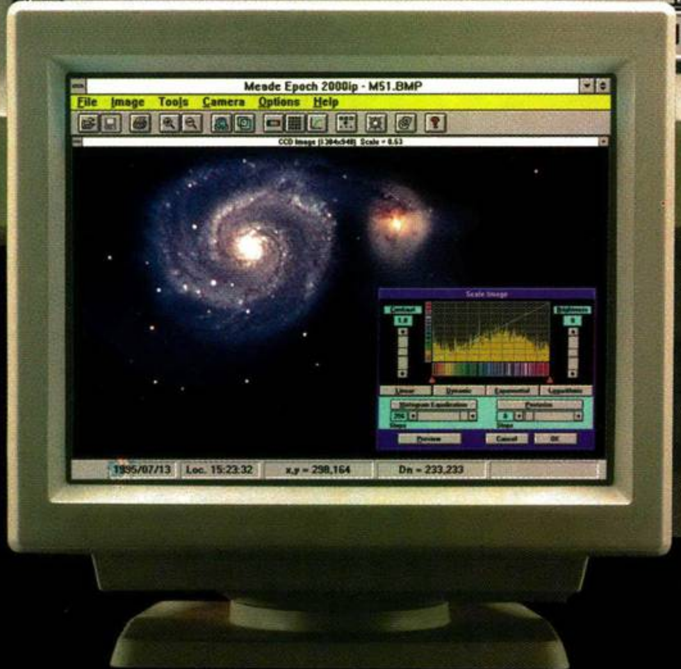
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LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk . . **25**

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MEA

LX200

The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models ***combined***. Consider these *standard-equipment* specifications:

- **Superb Optics:** LX200 imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of over 64,350 objects in the onboard database, *to a precision of one arc-minute or better.*
- **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an auto cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); complete operating instructions.

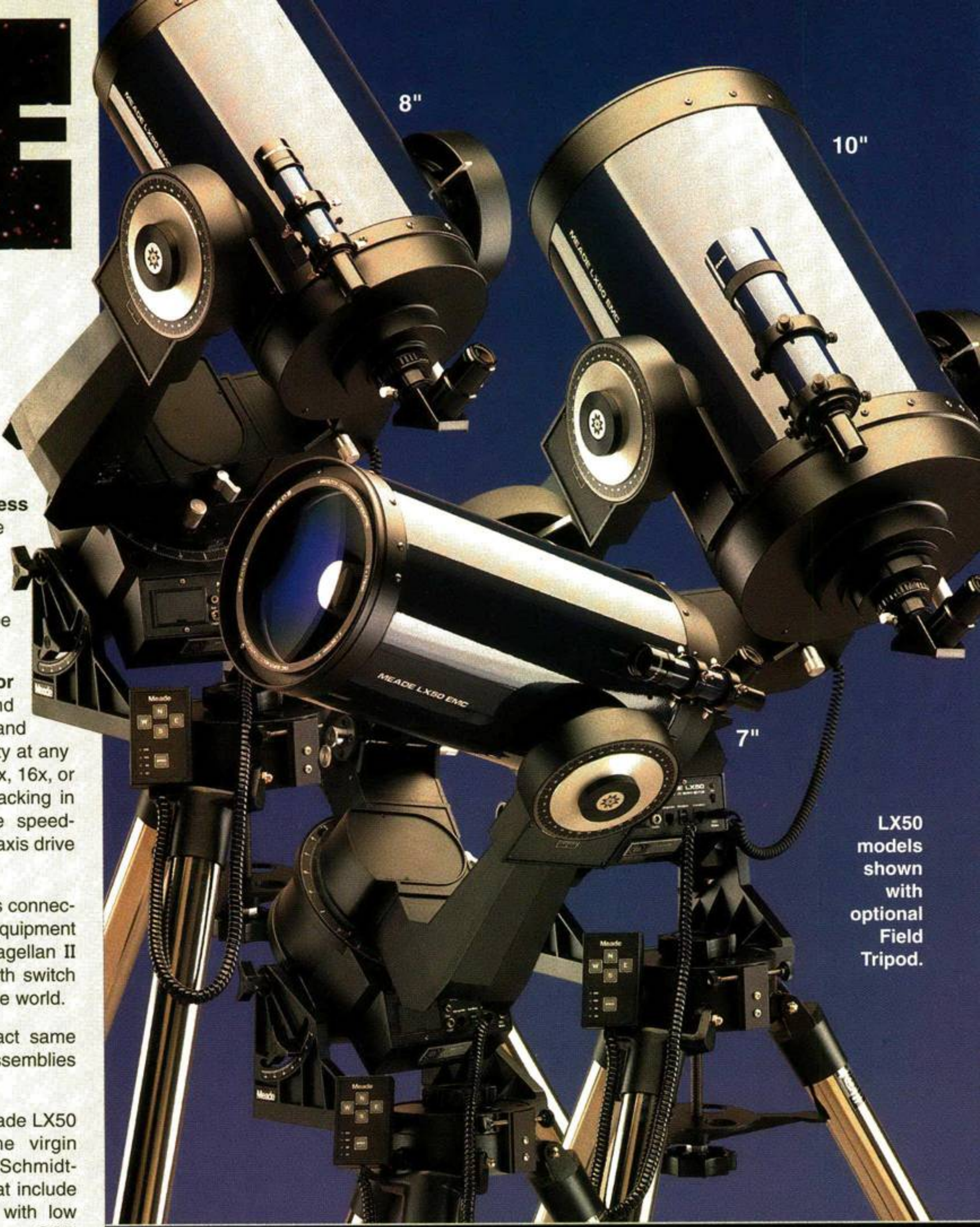
8" LX200 Schmidt-Cassegrain	**$2495.**
10" LX200 Schmidt-Cassegrain	**2895.**
12" LX200 Schmidt-Cassegrain	**3995.**
7" LX200 Maksutov-Cassegrain	**2995.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

ADE

LX50

Advanced technology at the most affordable prices ever.



LX50 models shown with optional Field Tripod.

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from four AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting four (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1195.**
10" LX50 Schmidt-Cassegrain	**1495.**
7" LX50 Maksutov-Cassegrain	**1595.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y, only	**1195.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), completely concealed in special LX50 encoder compartments. ■ Quick 2-star alignment. ■ Large 32-character, red-backlighted display. ■ 4-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$395.** + $15 packing and shipping in the 48 states.

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$1095.

12" f/4.8
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10" f/4.5
$595.

8" f/6
$425.

6" f/8
$325.

All models shown with optional #637 6 x 30mm or #545 8 x 50mm viewfinders.

Compare *feature-for-feature* with other similarly priced Dobsonians!

- **Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass:** Unlike the plate glass optics of other Dobsonians that can become thermally unstable (especially in larger apertures), Meade Dobsonians are made of Grade-A, fine-annealed Pyrex—the exact same professional-quality optics used on Meade Starfinder Equatorials.
- **Precision Components:** Including a full-size rack-and-pinion focuser (1.25") with 2.6" travel and fully-adjustable *4-vane* secondary mirror system.
- **Rigid, Durable, Beautiful Dobsonian Mountings**, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the location and tracking of celestial objects.
- **Optical Tubes:** Starfinder Dobsonians include the same strong, spiral-wound optical tubes used on Starfinder Equatorials *(right)*. All telescopes include a multi-coated MA25mm eyepiece; each tube is factory pre-drilled for the optional 6 x 30mm or 8 x 50mm viewfinder.
- **Performance!** A Meade Starfinder Dobsonian or Equatorial opens up the skies to an extremely wide range of serious visual observing: all 110 Messier objects, thousands of NGC objects—nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning, high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder equatorials may be used, in addition, for lunar and planetary photography and even for limited deep-space photography.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$39; 8"–$49; 10"–$69; 12.5"–$79. 16"–$45 packing, shipped truck freight collect.

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At the time you order any Meade Dobsonian, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, *and* the Meade #637 6 x 30mm viewfinder with metal bracket for a **total of $49.95!** *Purchased separately, the 2 eyepieces and viewfinder sell for $125.85!* Offer valid until further notice.

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Computerize your Meade® Starfinder™ Dobsonian or Equatorial for only $295!

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- Don't spend $400, $500, or $600 for a computer system with fewer features! Designed and manufactured at the Meade Irvine facility, the Magellan I includes one of the largest object databases available, incorporates only premium-grade components, and sells for a low $295!

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ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM
U.S.A.

Actual Size: 4" x 5" x 1.25"

- **Easy to Use!** Just input the R.A. and Dec. of the object you wish to observe, or call up an object from Magellan's massive database. Magellan allows you to slew the telescope manually to the object and place it in the visual field, quickly and precisely.
- **Fast 2-Star Alignment:** Point the telescope at 2 bright stars selected from the star database, and the computer is aligned in *seconds.* No need to input time or date, latitude or longitude. Magellan's powerful microprocessor calculates telescope position in milliseconds and directs your movements of the telescope for fast, accurate object location.

Meade Magellan II Computer-Corrector for Starfinder Equatorials

Plug the Magellan II into the control panel of your Meade DC-powered Starfinder Equatorial *(right)* and you have *all the capabilities of the Magellan I (above)* ***plus*** a 4-speed, dual-axis, drive-corrector/microslewing system!

Includes: Magellan II hand controller *(right)* with 4 dual-axis speed rates (2x, 8x, 16x, 32x sidereal); high-resolution 4096-pulse encoders for both axes; electric Declination control system; 12,218-object computer database; 2-star alignment; RS-232 serial interface. (For Meade *DC-powered* Starfinder Equatorials, only.)

#2018: for Starfinder Equatorial
6", 8", or 10" . . . . $495.
#2019: for Starfinder Equatorial 16" . . . 595.

Prices plus $20 packing & shipping in the 48 states.

INDER
UTERS

■ **High-Resolution 4096-pulse Encoders:** Each Magellan system includes two premium-grade, high-resolution encoders. Encoder precision is 5.3 arc minutes.

■ **Large 32-Character LCD Red-Backlighted Display:** The same LCD display included with the Meade LX200 hand controller. Includes variable illumination from dim to bright.

■ **12,218-Object Database:** A database that includes an amazing array of objects:

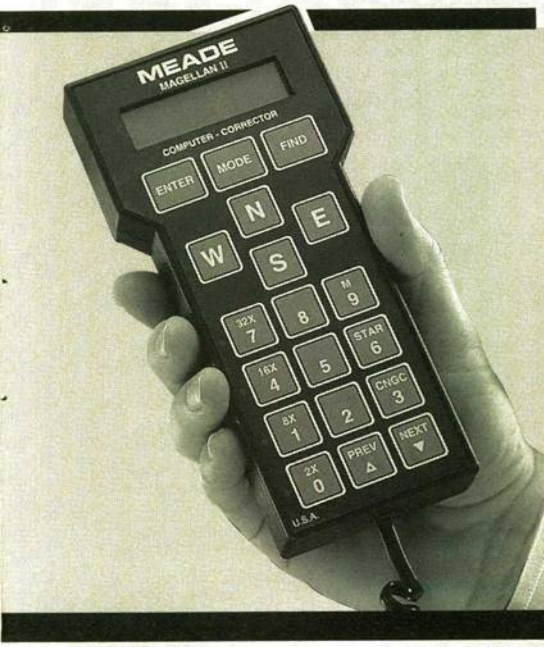
7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

■ **Supplied Complete!** With other computers you pay *once* for the basic controller and then pay *again* for the "Encoder Installation Package." Meade Magellan Systems are supplied **complete** with: controller/display unit (4" x 5" x 1.25"); encoders for both telescope axes; RS-232 serial interface; bracket for convenient placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan is ready to use. First-time installation is quick and simple.

Meade Magellan I Telescope Computer Systems

#2010:	**for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16"**	**$295.**
#2011:	**for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10"**	**295.**
#2012:	**for Meade (DC-powered) Starfinder Equatorial 16**	**295.**

All prices plus $15 packing & shipping in the 48 states. Prices shown are suggested U.S. national mail-order retail prices. For additional information on Meade Magellan systems, send for your free copy of **Meade Bulletin 2900.**



MEADE
STARFINDER EQUATORIALS
MEADE
MEADE DC DRIVE SYSTEM
16" f/4.5 $2495.
10" f/4.5: $799.95
8" f/6: $699.95
6" f/8: $599.95

Battery-powered motor drives for fully cordless operation!

Standard equipment on 6", 8", and 10" equatorial models includes:

■ **Superb Optical System:** Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

■ **Precision Equatorial Mount:** Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

■ **Battery-Powered Cordless Drive System!** Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 4 (user-supplied) AA-size batteries inserted through the drive cover. Control panel *(see inset, above)* also permits powering of telescope from 12v. auto cigarette lighter plug, using optional 25' cord.

■ **Accessories and Components:** Rack-and-pinion focuser (1.25") with 2.6" travel; #637 6 x 30mm viewfinder; multi-coated MA25mm (1.25") eyepiece; strong, durable, spiral-wound optical tube with attractive white finish.

■ **Starfinder Equatorial 16:** Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6"-dia. pier, 4 x AA-size battery-powered worm gear drive, 8 x 50mm viewfinder, #682 giant (2" & 1.25") rack-and-pinion focuser.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$65; 8"–$75; 10"– $90. 16"–$55 packing, shipped truck freight collect.

To Order: Contact your authorized Meade Advanced Products Dealer. All prices shown are suggested USA mail-order retail prices.

Meade 1995-96 General Catalog, $3.00 postpaid, is available from your authorized Meade dealer or directly from Meade Instruments.

ACCESSORY OFFER!

At the time you order any Meade Starfinder Equatorial Telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, for a **total of $29.95!** *Purchased separately, the 2 eyepieces sell for $75.90!* Offer valid until further notice.

ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur
16542 Millikan Avenue, Irvine, Calif. 92714 ☐ (714) 756-2291
FAX: (714) 756-1450

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Series 4000™
2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (3.29)

MEADE
TELESCOPES AND ACCESSORIES

Series 4000™ Super Plössls
52°

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm each: **$87.95** (3.45)

32mm (52°); **40mm** (44°) each: **109.95** (3.79)

56mm (52°; 2") **229.95** (5.48)

Series 4000™
f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. **Internal batteries included.** Multi-coated optics. Bullseye reticle. 1.25"

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 4000™
Super Wide Angle
67°

For exquisite wide-angle images at low-to-medium powers, ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8, 18, and 24.5mm are superb complements to the #140 Barlow, above.

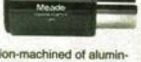
Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $159.95** (3.49); **18mm: 169.95** (3.69); **24.5mm: 199.95** (3.89); **32mm** (2"): **279.95** (4.78); **40mm** (2"): **339.95** (5.48)

Series 4000™
Ultra Wide Angle
84°

The ultimate eyepieces; extreme image sharpness over an amazing 84° field.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)–**4.7mm: $179.95** (3.29); **6.7mm: 219.95** (3.29); **8.8mm** (1.25"/2"): **269.95** (4.78); **14mm** (1.25"/2"): **329.95** (5.48)

Camera Adapters



Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

Meade Model 285
60mm f/15 Equatorial Refractor

Complete with tripod and 2 eyepieces.

Includes the same equatorial mount of larger Meade models at right. Dual-axis worm-gear slow-motion controls permit easy tracking of astronomical objects. Two eyepieces (1.25") for powers of 36X and 100X. Multi-coated objective lens resolves to the theoretical limit.

Accepts #531 Motor Drive *(below)*

$299 (16.55)

Meade Model 4500
4.5" f/8 Equatorial Reflector

World's largest-selling 4.5" telescope!

The finest first-telescope available. *Provides stunning optical performance on the Moon, planets, and hundreds of deep-space objects.* Precision equatorial mount includes worm-gear slow-motion controls in RA and Dec and full-length (50") aluminum tripod. 6 x 30 finder, rack-and-pinion focuser (1.25"), multi-coated MA 25mm eyepiece (1.25"). *Immediate delivery through your authorized Meade dealer.*

Fully automatic tracking with #531 Motor Drive *(below)*

$399 (22.40)

Meade Model 390
90mm f/11 Altazimuth Refractor

Perfect for land-viewing or astronomy.

Excellent imaging power for any terrestrial application, or for observing hundreds of astronomical objects in sharp detail. Smooth dual-axis controls; multi-coated optics. Supplied with 6 x 30 finder, MA25mm eyepiece (1.25"), aluminum tripod.

Includes flexible steel cable controls on both axes.

$499 (23.60)

Meade Model 395
90mm f/11 Equatorial Refractor

Multi-coated, high-resolution optics.

Includes flexible steel cable controls on both axes.

Accepts #531 Motor Drive *(below)*

Precision Meade objective lens far surpasses other telescopes selling at similar prices. Complete with equatorial mount, aluminum tripod, 6 x 30 finder, MA 25mm eyepiece (1.25"). Thousands now in use.

$599 (24.65)

Meade intermediate-size telescopes are the world's largest-selling quality telescopes of their apertures. *They are the only telescopes in this price range designed by Meade engineers and manufactured to exclusive Meade specifications.* Each instrument includes mechanical components, gear systems, and accessories specifically intended for serious applications of the beginning to intermediate amateur astronomer. American-size 1.25" barrel-diameter eyepieces, threaded for filters, are included with all models. Large cable controls facilitate the tracking of astronomical or terrestrial objects, and, on equatorial models, the optional Meade #531 Motor Drive *(see right)* enables fully automatic tracking of astronomical objects.

#531 Motor Drive

Attaches in seconds to the equatorial mounts of Meade Models 285, 4500 or 395 telescopes. Permits fully automatic tracking of celestial objects. Cordless operation anywhere in the world from 3 (user-supplied) AA batteries.

$99.50 (4.78)

Series 3000™ Plössls
50°

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce excellent results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

Series 3000™ Plössl 40mm 44°

A perfect complement to the Series 3000 Plössls at left, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, multi-coated. Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

$79.95 (3.79)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (2.98)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, at right. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (3.45)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

HOW TO ORDER

- Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.
- Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in ( ) next to each price.
- Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

CITY CAMERA, Dearborn, MI.
Orders: 800-359-5085; Info.: 313-846-3922.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Info/IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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FREE! $800 CCD Equipment System!

Now, for a limited time, when you purchase a Meade Pictor 416 or 1616 CCD imager at the regular price, **we'll include an $800 Meade CCD Equipment System—everything you need for advanced CCD imaging—absolutely FREE!** Purchased separately, the CCD Equipment System is priced at $807 and includes these important products:

Meade Pictor 201 Autoguider: Allows completely automatic guiding of your Pictor camera during CCD imaging or your 35mm camera during long-exposure astrophotography.	$395.
Meade CCD Off-Axis Guider System: Complete with adapters for 1.25" eyepiece holders and for Schmidt-Cassegrain rear-cell threads. Use with the Pictor 201 on guide stars to 10th-magnitude.	119.
Meade CCD Image-Orientation Adapter: Threads into the Off-Axis Guider and permits precise image orientation on the CCD chip.	35.
Meade Epoch 2000ip Image Processing Software: Professional Windows-based image processing that permits the enhancement and analysis of CCD images using the most advanced techniques, including dynamic scaling, histogram equalization, image convolution, unsharp masking, median filtering, RGB merging, and more.	199.
Meade Foam-Lined Carrying Case (19" x 14" x 7"): Provides for secure storage and transport of your Pictor 416 or 1616 CCD imager as well as all items of the CCD Equipment System described above.	59.
Total price of all items if purchased separately:	$807.

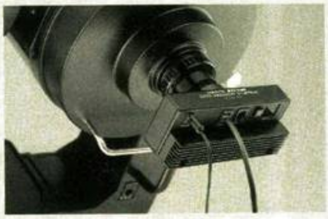
The Meade Pictor 416 CCD Imaging Camera is packed, at no additional charge, with the **Meade $800 CCD Equipment System** during the period of this special offer.

EPOCH 2000
EPOCH 2000
MEADE PICTOR
MEADE
PICTOR
MEADE PICTOR
Meade OFF-AXIS GUIDER

The Trifid Nebula (M20): Pictor 1616; a 5-minute exposure by Jack Newton with the Meade 7" f/9 *ED* Apochromatic Refractor.

Pictor 201 Autoguider: For flawless, ultraprecise autoguiding during long-exposure astrophotography or CCD imaging. Automatically locks on to guide stars as faint as 10th-magnitude and makes all required dual-axis corrections. Results in perfectly guided astrophotographs or CCD images during even the longest of exposures. Completely self-contained; no host PC required. **$395.** + $10 packing & shipping in 48 states.

Pictor 208 Autoguider/Imager: For an amazingly low price, the 208 gives impressive imaging capability even to the novice. On telescopes of 4" aperture and larger, the Pictor 208 yields very satisfying results and, in addition, is a full-capability autoguider, containing the exact same autoguider hardware and software as the Pictor 201, above. The 208 incorporates the Texas Instruments TC-255 microchip, by far the largest, highest-resolution chip available in any CCD unit in its price range. **$795.** + $15 P & S



Pictor 216 CCD Autoguider/Imager: Identical in operation and size to the 208, the Pictor 216 includes a 16-bit A/D converter for 65,536 brightness levels. The result is a level of image quality only obtainable on competing units that sell for almost twice the 216's price. Combining high-resolution imaging with low dark current, the Pictor 216 satisfies the long-term CCD imaging requirements of the majority of serious amateurs. **$1295.** + $15 P & S

Pictor 416 CCD Autoguider/Imager: Armed with the powerful Kodak KAF-0400 CCD microchip, the Pictor 416 is the most advanced high-resolution CCD system available under $5000. And, with its standard-equipment SCSI interface, the 416 can full-frame download in *one second!* The Pictor 416 is a powerful CCD system on any telescope; attached to a Meade LX200, its capabilities are truly awesome. The auto-mosaic feature, for example, permits the imaging of an arbitrarily large sky area **automatically** on user command. **$2495.** + $25 P & S

Pictor 1616 Autoguider/Imager: For professional-level applications the Pictor 1616 utilizes the Kodak KAF-1600 microchip, one of the largest (13.80 x 9.20mm) CCD chips in commercial production. Identical in pixel density and dark current to the 416, but with *four times* the chip area, the 1616 permits the imaging of very large sky areas: a sky area of 23' x 15' with an 8" f/10 Schmidt-Cassegrain, almost one-half the lunar surface in a single exposure. The 1616 is the finest CCD imaging system available at under-$10,000. **$6495.** + $40 P & S

The special Meade CCD Equipment System offer is effective beginning July 20, 1995, at participating Meade dealers in the U.S.A. and Canada. *This offer is valid until further notice and may be withdrawn at any time.* ■ All prices shown are suggested U.S. national mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable. ■ For safety reasons AC-powered personal computers should be used indoors only. ■ The Meade brochure ***CCD Imaging Made Simple*** is available free of charge, or send $3.00 for the 76-page **Meade *1995 General Catalog*.**

AUTHORIZED U.S. MAIL-ORDER DEALERS

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CALIFORNIA TELESCOPE COMPANY, Burbank, CA
Orders & Information: 818-505-8424

CITY CAMERA, Dearborn, MI, Orders: 800-359-5085; Information: 313-846-3922

FOCUS CAMERA, Brooklyn, NY, Orders: 800-221-0828; Information: 718-436-6262

LUMICON, Livermore, CA, Orders: 800-767-9576; Information: 510-447-9570

SHUTAN CAMERA & VIDEO, Chicago, IL, Orders: 800-621-2248;
Illinois & Information: 312-332-2000

Canada:

EFSTONSCIENCE, Toronto, Ontario, Orders & Information: 416-787-4581

KHAN SCOPE CENTRE, Toronto, Ontario, Orders & Information: 416-783-4140

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BINOCULAR GUIDERS

Eliminates tripod hugging, arm fatigue, unsteady viewing ★ Views from zenith to horizon, 360° in azimuth ★ Smooth action ★ Three adjustable brakes ★ Heavy construction ★ Weighs 7 lbs. ★ Mounts on standard tripod

For 60mm binoculars & under **$140**
For 70-80mm binoculars **$160**

BINOCULAR OBSERVING CHAIR

★ Rotates 360°, views from zenith to horizon ★ Easily adjusts to observing positions ★ Tension adjustment for binocular sizes ★ Safety wheel promotes steadiness ★ Back removes for transportation ★ Weighs 35 lbs.
$350 plus UPS ship'g in USA

NEW!
MICROSTEPPING TELESCOPE CONTROLLER

★ High performance tracking system with **FAST SLEW** for ultimate control.
$1600-$2100

Astrophotography at an affordable price!

CAMERA TRACKERS

CHOOSE FROM THREE MODELS
★ Solar and / or Sidereal tracking ★ 120 VAC, 12 VDC or dual hemisphere ★ For camera lenses up to 1000mm ★ Carries up to 7 lbs ★ Mounts on standard tripod ★ Optional pole finderscope ★ Weighs only 9 lbs
$300-380

VISTA DRIVE CORRECTORS
JP400 / 500 Series—**$325-385**

★ Designed to drive Meade, Schaefer, Byers, Celestron C-14, etc., with high precision, resolution and accuracy ★ Available with options for SBIG, single or dual axis interfacing and 240 VAC, 50 Hz foreign operation ★ Synchronous and stepper systems

Other systems available from **$125-$1500**

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For full line catalog send $2.00 to VISTA INSTRUMENT CO., P.O. Box 1919-A, Santa Maria, CA 93454.

LETTERS

puter and processes them in Adobe Photoshop, contends that it's easy to tell when a photographer has gone "too far." He is careful to point out that he doesn't "paint" the images, but only enhances them.

But it's a disturbing trend for conventional photographers, though, this drive to see who is a "better" photographer by pushing color and contrast. Starlight from the distant objects we observe is very old, and should be treated with respect.

It would be sad if we have to ask the same question about photos in astronomy magazines that we do of the glamour ones: "Is it real or airbrushed?" — *Jason Ware, Frisco, Texas, jason@pixel.cirrus.com*

Atlases on the Web

Your readers may be interested in a library exhibition catalog that we've just placed on the World Wide Web. It's called "Out of This World: The Golden Age of the Celestial Atlas."

The exhibition (at the Linda Hall Library) contains 43 celestial atlases of historical significance, including Bayer's *Uranometria*, Hevelius' *Firmamentum*, Bode's *Uranographia*, and Flamsteed's *Atlas*.

The on-line catalog has at least two images from each catalog, in both medium- and high-resolution formats, and some are quite spectacular.

Users may access the catalog at http://www.lhl.lib.mo.us/pubserv/hos/stars/welcome.htm. — *William B. Ashworth, Jr., Dept. of History, University of Missouri, Kansas City, Missouri*

Light Pollution Victory

I want to let you know about a small victory in the war on light pollution. The city of Markham, Ontario has established four "heritage areas," and these have been used to combat Esso Oil's new gas station canopies. These huge, white glowing surfaces have been compared to alien spaceships, and their light output is enormous.

Markham, a northern suburb of Toronto, got Esso to install smaller, retro canopies similar to those used half a century ago. The light is less intense and focuses more on the gas area itself. — *T. Bachorczyk, Kenmore, New York*

Bringing Large Format into Focus

Your article, "Big on Celestial Photography" (November 1995), contained much of interest but also gave some erroneous information that could get newcomers into trouble.

The "view cameras" listed in the table are definitely not adequate for this task. (A 4x5 camera rigid enough to withstand 1 to 2 hour exposures can be built rather easily, however.) View cameras that *are* adequate for astrophotography are extremely expensive and offer slow f/ratios. (To be fair, the authors briefly mention that.) Also, many more choices for 6x7cm cameras are available than those listed.

In terms of film selection, few films are available in 120, 4x5, and larger formats. Processing 120 film is highly difficult, by the way, and often leads to problems of nonuniformity.

I think the authors could have served the readership better by confining their comments to 6x7cm and smaller formats, and by providing more info in this area. — *Brad D. Wallis, Thousand Oaks, California, wallis@pepe.jpl.nasa.gov*

Grill Away the Lithium

I enjoyed the article "Another Brown Dwarf" (January 1996). On page 26, however, the article states, "Over time, heat from a star's nuclear furnace destroys lithium in its atmosphere." I'm sympathetic to a dramatic turn of phrase, but this seems too far from reality. Heat by itself is hard pressed to destroy elements and certainly not in stellar atmospheres. What I understand happens is that, over time, atmospheric lithium convects to a low-mass star's core, where it is consumed by nuclear reactions. — *Gerald Nordley, Sunnyvale, California, GDNordley@aol.com*

Spaced out Stewart

Regarding the interview with Patrick Stewart (Forum, December 1995), if he really believes that "nothing on Star Trek was fantasy . . . it is all scientifically possible," then I think he's been spending a little too much time on the Holodeck. — *Kevin Withers, 72510.2627@CompuServe.com*

Patrick Stewart came across as a really nice guy, but his opinions regarding the science on Star Trek are just a touch naive. This is a series that has featured subatomic bacteria, two planets colliding to form a star, shock waves in empty space, and some very confused ideas about gravity.

If you want science fiction with some real science in it, let me recommend a book by Larry Niven or Stephen Baxter. — *Paul Beardsley, paul.beardsley@gecm.com*

Close Encounters Review Parsecs Off Target

For a science publication, you seem to have forgotten your calling by publishing a gushingly favorable review of C. D. B. Bryan's *Close Encounters of the Fourth Kind.*

In describing Bryan as a "neutral" observer of the MIT conference on UFOs, you ignored the fact that he was given open access to an invitation-only conference from which the objective press was excluded. And by characterizing Bryan's lack of experience with UFOs as "desirable," you neglected to report that he accepts at face value stories that even true believers discredit.

To assert that Bryan's book is valuable because "you cannot get away from the numbers: millions of people worldwide believe they have been contacted by aliens," is both logically faulty and foolish. It's equally true that millions of people worldwide are certifiably psychotic. That's a more rational explanation for the widespread reports of alien abductions. — *Lew Phelps, lewphelps@aol.com* ☐

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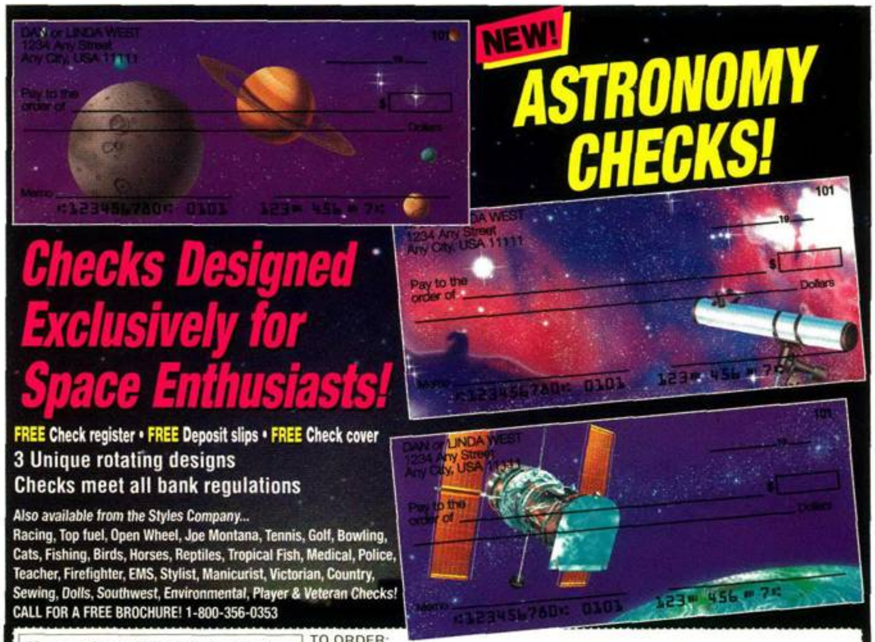
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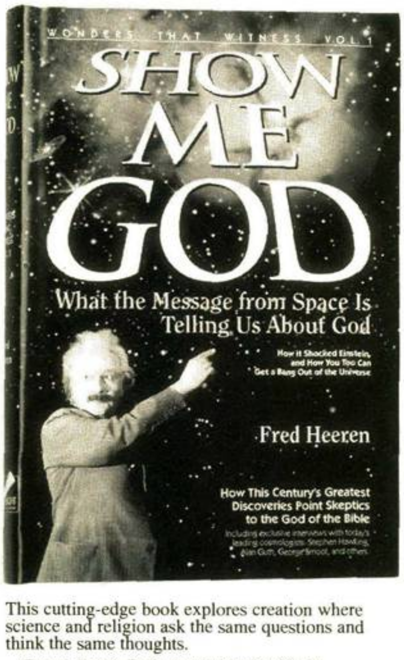
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Standard accessories (the same on both models), include a 20mm Eyepiece – 1¼", 6x30 Finderscope with an 8° field and a Star Diagonal – 1¼". Weight is 39 lbs.

Optical tube assemblies of the 4" refractors are available separately and include tube rings, mounting plate and finderscope.

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The glossy black telescope optical tube is made of aluminum. The sturdy altazimuth mount has a slow-motion control rod for vertical adjustments. The rigid, adjustable wood tripod includes an accessory tray.

Standard accessories include a 20mm H – .96" Eyepiece (35x), 6mm SR – .96" Eyepiece (117x), 2x *Barlow Lens* – .96", 5x24 Finderscope and a 90° Diagonal.

FIRSTSCOPE 60 DELUXE

The same as the Firstscope 60 except that all the .96" items are replaced with a **hybrid 1¼" diagonal and two 1¼" eyepieces** – 25 SMA (28x) and 10mm SMA (70x).

Celestron offers two 60mm equatorial refractors – the Firstscope 60 EQ and the Firstscope 60 EQ Deluxe.

FIRSTSCOPE 60 EQ

Similar to the Firstscope 60 but the focal length for this telescope is 900mm (f/15).

Standard accessories include a 20mm H – .96" Eyepiece (45x), 12.5mm H – .96" Eyepiece (72x), 2x Barlow Lens – .96", 6x24 Finderscope and a 90° Diagonal. Weight is 11 lbs.

FIRSTSCOPE 60 EQ DELUXE

The same as the Firstscope 60 EQ except that all the .96" items are replaced with a **hybrid 1¼" diagonal and two 1¼" eyepieces** – 25mm SMA (36x) and 10mm SMA (90x).

The 1¼" accessories give you sharper images, a wider field of view and better eye relief. Weight is 11 lbs.

Celestron offers a premium grade 80mm (3.1") altazimuth refractor – **The Premium 80.** The premium built optics are made in Japan.

The Premium 80 is an ideal first telescope for the more serious beginning astronomer or terrestrial observer.

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Standard accessories include a 26mm multi-coated Plössl – 1¼" Eyepiece (35x) for a wide field of 1.4°, high quality 6x30 Finderscope and a versatile 45° Erect Image Diagonal – 1¼". Weight is 18 lbs.

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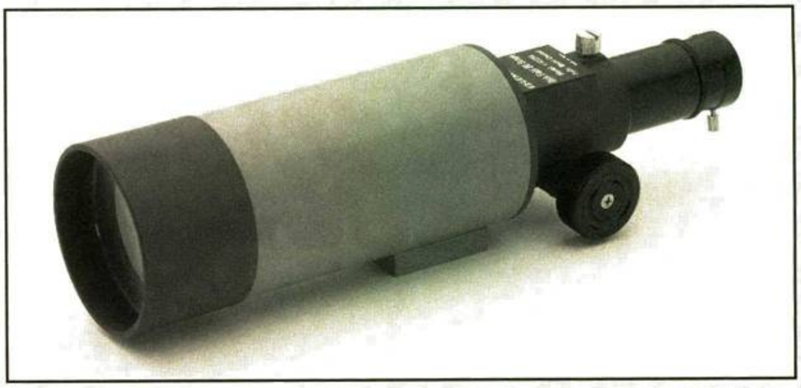

The optics are fully multi-coated to ensure high contrast levels and excellent resolution. The lens system contains an air-spaced doublet.

Bird watchers will appreciate the excellent performance in low light conditions as well as a near focus of ten feet.

Photographers will like the fast optical system – 400mm f/5. The weight is only 35 oz. Focusing is done with a fast, smooth rack and pinion focuser – 1.25". The length of the scope is 13.5".

The large aperture allows you to enjoy limited astronomical viewing of the Moon, planets, brighter nebulae and clusters. A built-in photo tripod adapter allows easy mounting to larger astronomical telescopes where the **Rich Field 80 Scope** becomes a piggyback camera lens, imaging lens or guidescope.

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ASTRO FORUM

The Hourglass

by Don Lago

In a ponderosa forest, buried in pine needles fallen over many years, I found a clock. Or what used to be a clock. It still had a face with numbers, but it had no hands, no frozen moment when the clock had broken.

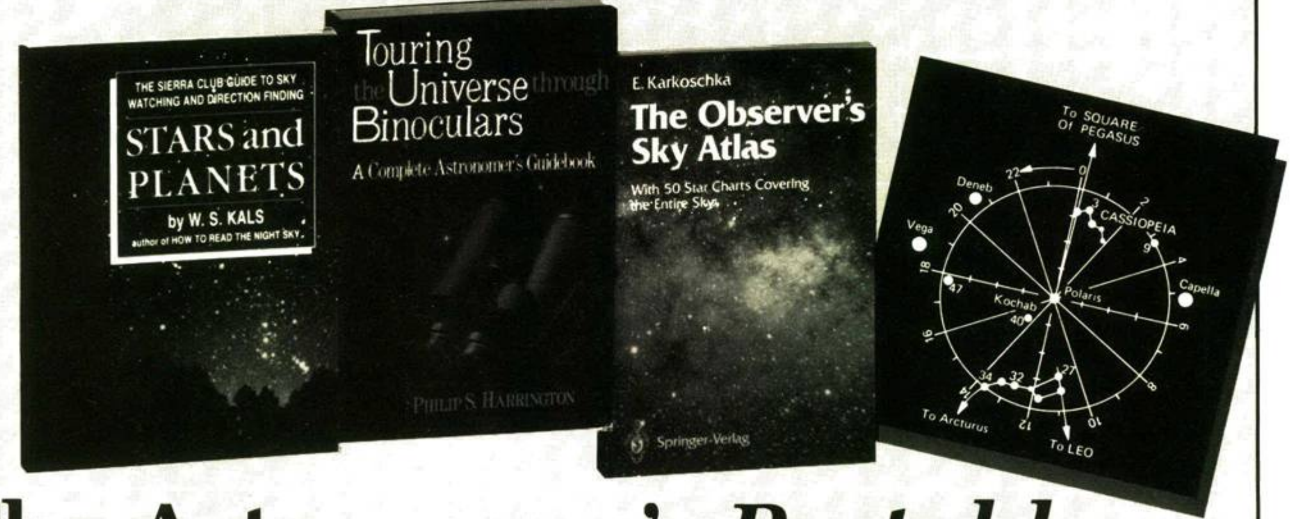
I found this piece of the past in a large trash pile in the woods behind Lowell Observatory in Flagstaff, Arizona. It was here on this volcanic mesa, in the early 1900s, that Andrew Douglass surveyed the sky and approved the site for Percival Lowell's observatory. In those days, the tiny logging town nested in the world's largest ponderosa pine forest.

The forest's boundary abruptly meets the nearby desert. Douglass, intrigued with the Sun and whether or not solar output varied, wondered if ponderosas might support his interest in this subject. He reasoned that because the trees were sensitive indicators of precipitation, they would also disclose something about solar activity. At a local lumberyard, Douglass discovered that the ponderosa's rings varied greatly in widths and seemed to correspond with locally recorded rainfalls. He surmised that if rainfall correlated with the Sun's presence, he could then plot centuries of solar activity in tree rings.

Douglass also noticed that sometimes a sequence of thick and thin rings occurring near the core of one tree could also be found near the outside of another. This allowed him to cross-date different trees and extend his record steadily backwards. He found a reliable eleven-year cycle in ring growth, except for a seventy-year stretch starting in the 1650s, a missing interval also reported by the British astronomer Walter Maunder in 1894.

Douglass needed to fill the gap.

At the time, the oldest living ponderosas were 500 years old; to extend his record farther back, he had to find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Astronomy 4/96

another source. He discovered it nearby in the ruins of another civilization.

The trash heap before me contains shoes, cosmetic jars, the springs of a bed, various household fixtures, the cans and jars of hundreds of meals, the bones of some holiday feast, and what I suppose are pieces of astronomical apparatus. I reach down and pick up an old bottle. As I turn it upside down, some dirt runs out, like sand draining from an hourglass. I envision the mound of trash as the sand of a vanished time collected in the bottom of a huge hourglass. Even the trees around me are filled with time. I reach out and touch the bark, feeling ancient sunlight. This is what Douglass understood.

Geoff Chester

To find older trees, Douglass traveled to Chaco Canyon, Mesa Verde, and other Native American ruins. The people who had lived there used ponderosa logs to support the roofs and window frames of their pueblos. At Chaco Canyon in New Mexico, the Anasazi had used 100,000 ponderosa logs, dragging them from mesas thirty miles away. Now the Anasazi villages were in ruins, filled with broken pottery and sand.

Using a boring tool to drill samples from the walls, Douglass cross-dated logs from different ruins, eventually building a timeline 250 years long. He inevitably gave archaeologists an invaluable tool. Now instead of guessing the sequence of Anasazi sites or trying to deduce it from pottery styles, they could know it precisely. Douglass also found evidence of a widespread drought that may have forced the Anasazi to abandon their cities. Though the Anasazi had worshipped and carefully surveyed the Sun for centuries, they perhaps fell victim to some fluctuation of it.

But there still was a void to fill between the 250-year Anasazi record and the 500-year modern record. To satisfy it, Douglass went to the Hopi villages, occupied since Anasazi times. Ponderosa-roofed kivas, which connected Hopis to the cycles of

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nature, connected them with larger cycles than they had realized. Though Hopi priests wouldn't let Douglass bore into a kiva, the samples he took from Hopi ruins allowed him to positively date its first ruin, his new science of dendrochronology. To cinch the past and present more tightly, Douglass used pottery styles that pointed to a ruin from the missing period. At last he completed his tree-ring history, dating nearly 2,000 years of southwestern cultures more precisely than I can date this pile of astronomical refuse.

On the backside of the observatory's mesa, I return to my cabin made of ponderosa pine logs. Between me and the mesa there is no other human structure, only forest. On the wood beside my door are claw marks where a bear climbed down from the roof. I glance at the ground, searching for red pottery shards. Every time a good rain washes the trail, another shard emerges. The ancestors of the Hopis lived here long ago. Perhaps the pottery shards emerge more frequently according to an eleven-year sunspot cycle. I pick up the shards and take them inside, placing them in a modern Hopi pot decorated with rain symbols.

Through my window at night starlight rains in, flickering with the swaying pine branches. I am riding in a time capsule. Even as the logs of my cabin have taken on the shape of human need, they remember their membership in the cycles of forest and rain and Sun. They remind me that I fit not just in a human structure, but also in those larger cycles. In the forest, time undulates onward. From every star the past ripples into the present.

In the sky all around me looms a landscape of ruins, of galaxies that long ago collasped into black holes, of quasars that dimmed, of star clusters that shed the shapes we see in our telescopes. Astronomers are the archaeologists of the sky, digging through the ancient piles of light left by galaxies.

And all night long the hourglass grows emptier. □

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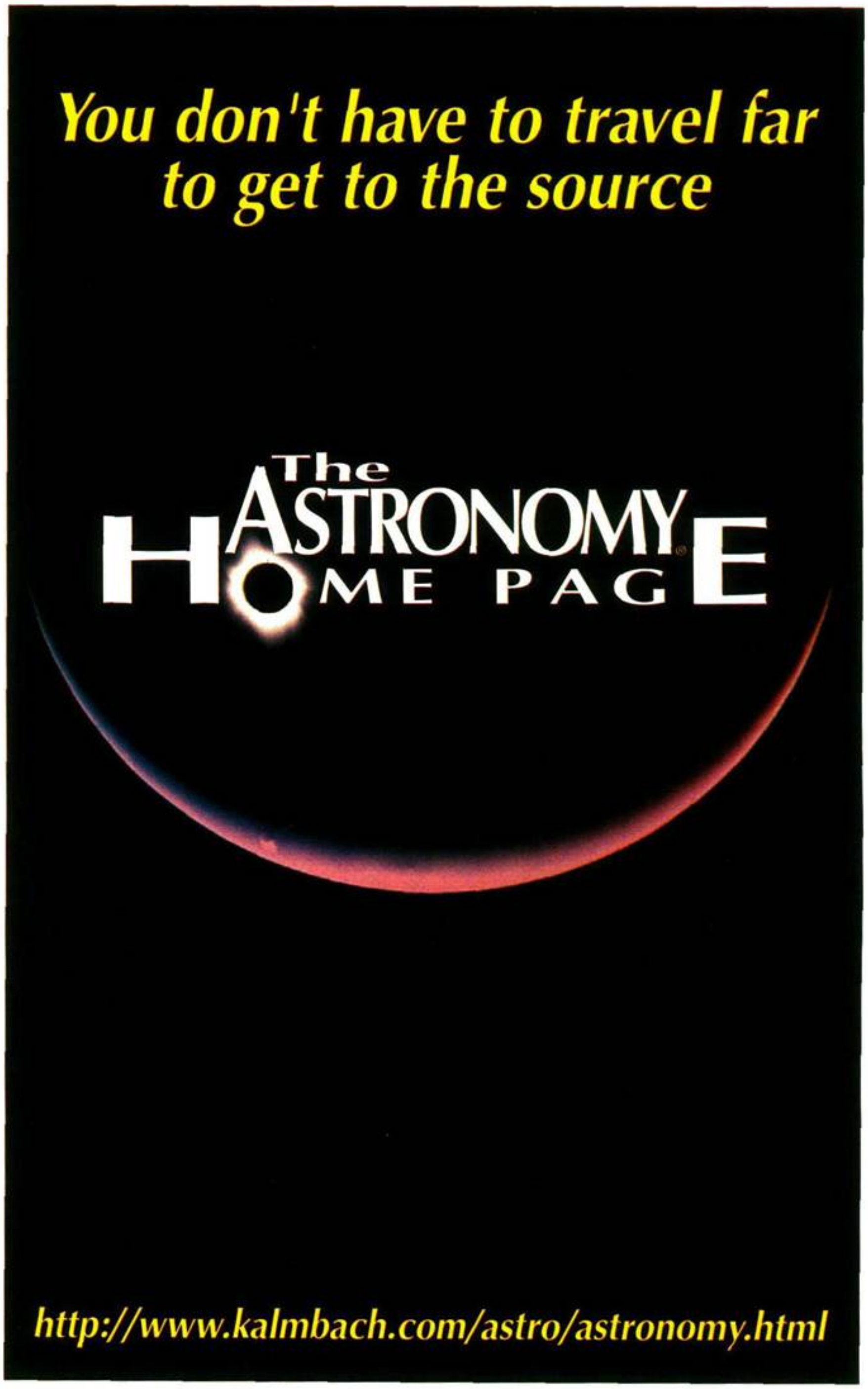

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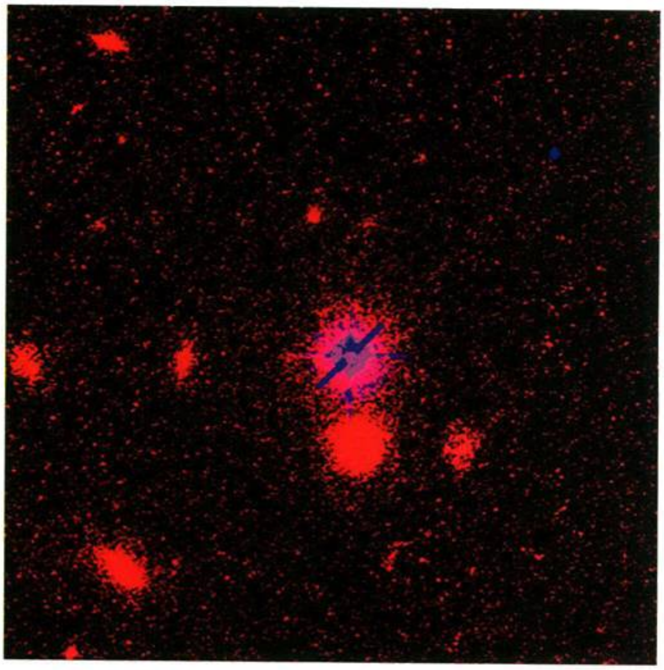
ASTRO NEWS

Not-So-Naked Quasars



Kim McLeod (Harvard-Smithsonian Center for Astrophysics)

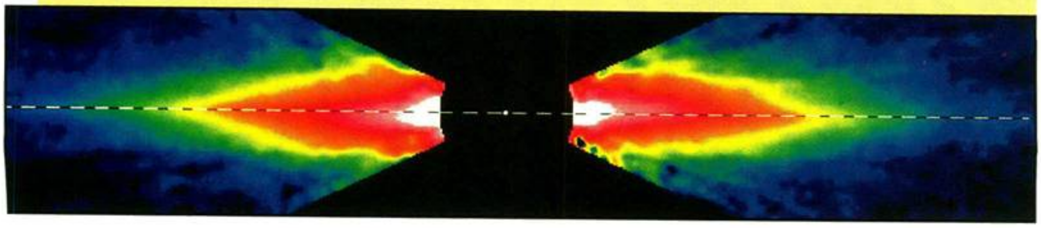
PROPERLY CLOTHED after all. This Hubble Space Telescope image shows a host galaxy in red surrounding a quasar (blue). The red circle below the galaxy is a companion galaxy.

In January 1995 astronomers reported that the Hubble Space Telescope had photographed 11 relatively nearby quasars that didn't appear to be surrounded by host galaxies (see "A Galaxy of News," June 1995). Astronomers were dumbfounded because they thought quasars represented super-bright galactic cores — cores powered by supermassive black holes. The astonishing Hubble images of "naked quasars" prompted John Bahcall of the Institute for Advanced Study to remark, "This is a giant leap backwards in our understanding of quasars."

Well, astronomers can breathe a temporary sigh of relief. Kim McLeod of the Harvard-Smithsonian Center for Astrophysics and George Rieke of the University of Arizona have taken a closer look at the naked quasars, and have found that they may be properly clothed after all. When McLeod and Rieke smoothed some of the original Hubble images, which boosted the contrast, faint, outer regions of host galaxies showed up. McLeod and Rieke also saw "fuzz" surrounding the naked quasars in infrared images they took with the Steward Observatory's 2.3-meter telescope. The host galaxies all appear to be at least as massive as the Milky Way.

So has the matter of naked quasars been settled once and for all? "Never say never — it will only come back to haunt you," says McLeod. "It's possible that one day we'll find a quasar that lives in a very wimpy host galaxy. But it is fair to say that, to date, the most powerful quasars we've seen in the local universe do inhabit fairly hefty hosts."

DOES A PLANET LURK WITHIN? This new Hubble Space Telescope false-color image shows for the first time the inner region of the dusty disk surrounding the young star Beta Pictoris, located about 55 light-years away. The star's glare has hidden this region from ground-based observers. The pink-white inner edge of the disk is slightly tilted with respect to the red-yellow-green outer disk. This warp should have flattened itself out over time. But astronomers think the gravitational influence of a large planet may very well be disrupting the disk and maintaining the warp. If a planet exists, it lies somewhere within the cleared-out zone 5 billion miles (55 AU) from the star.



Chris Burrows (STScI and ESA), J. Krist (STScI), and NASA

Sea-Ice Ridges on Jupiter's Moon Europa?

Enigmatic ridges that crisscross Jupiter's ice-covered moon Europa may be pressure ridges like those that occur on Earth in polar sea-ice, say planetary scientists Robert Pappalardo of Brown University and Max Coon of Northwest Research Associates. If they are right, their finding adds to the evidence that the Jovian moon contains a global ocean of water beneath its icy crust.

The discovery came almost by accident. "I was showing him images of Europa that showed the ridges," says Pappalardo, "and he said, 'That looks like arctic sea-ice.'" Images taken near Europa's terminator by the Voyager spacecraft reveal long, thin ridges, while elsewhere on the satellite run dark streaks

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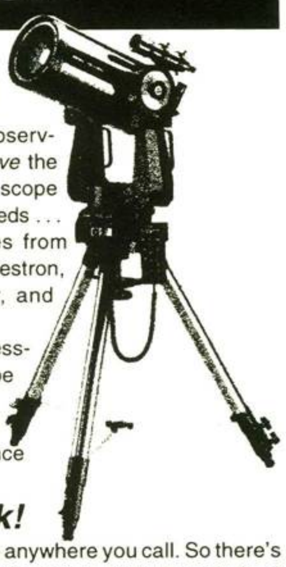

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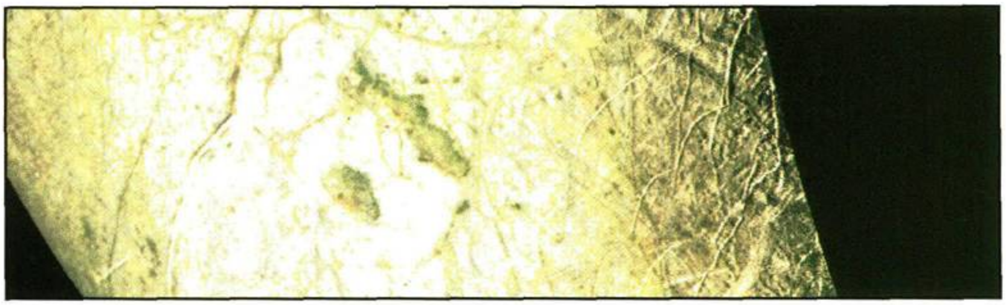


JPL/NASA

FRESHLY SQUEEZED ICE may account for the raised ridges on Jupiter's moon Europa, according to new findings which also seek to explain the bright central cores to some dark lineaments on the satellite.

with bright centers that also show some low relief.

With terrestrial sea-ice, notes Pappalardo, pressure ridges form when currents crunch two large floes of ice together. The floe margins buckle and overlap, piling up a ridge that typically reaches dozens of feet above the floe's surface while pushing into the water for a hundred feet or more.

Europa is suspected by scientists to have a rocky core covered with an ocean of liquid water several miles deep. Because of the frigid temperatures at Jupiter's distance from the Sun, the entire surface of this ocean is one global ice floe. Yet because Europa suffers tidal stresses from Jupiter and its neighbor moons, the ice surface breaks open from time to time and then refreezes, leaving telltale dark lineations called "leads" where the ice is freshest. After millions of years, a lead will freeze several kilometers thick and frost deposits on the surface will cause it to disappear.

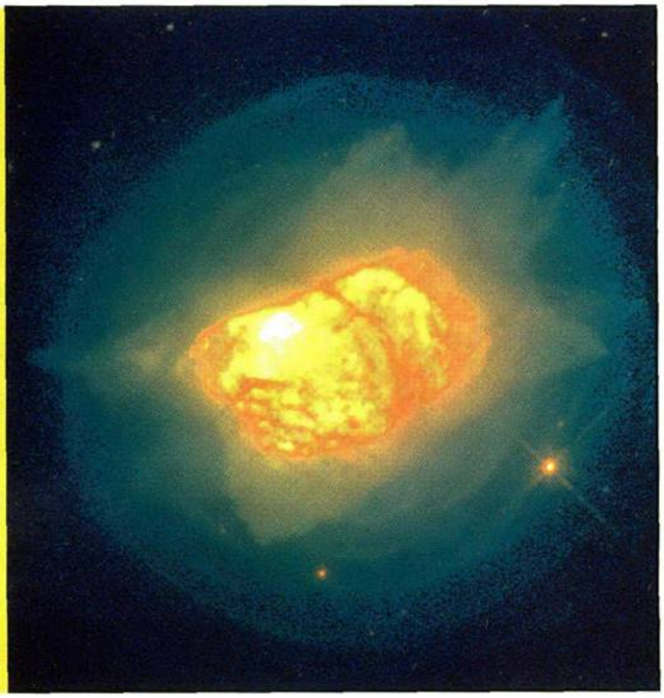
Pappalardo and Coon believe that the old ice on Europa is much too thick to buckle under the likely stresses. But they note that for a while after a lead opens and refreezes, its ice (always dark in color) will still be thin enough to pile up into a ridge if stressed. If creating the ridge caused the thin ice in the lead to crack, fresh water could leak out to flank the bright pressure ridges with new, dark ice. This, the researchers think, could explain the bright cores running down the centers of some leads.

Pappalardo and Coon reported on their work at a meeting of the American Geophysical Union in December 1995.

Putting the Sun in Its Place

Astronomers long ago showed that Earth doesn't lie at the center of the universe and, more recently, that the Sun doesn't occupy the center of the Galaxy. But where exactly are we located? Two new studies yield the best estimates yet of our location: about 27,000 light-years from the galactic center and 67 light-years north of the galactic plane.

To find the distance to the center of the Galaxy, Bruce Carney of the University of North Carolina, Chapel Hill, and his colleagues observed 58 RR Lyrae stars located in a small region of Sagittarius known as Baade's Window. They measured the infrared brightnesses of these pulsating variable stars with the 4-meter telescope at Cerro Tololo in Chile, reporting their results in the October 1995 issue of *The Astronomical Journal*. Because the stars all have nearly the same intrinsic brightness in the infrared, their distances can be computed by comparing that with their observed brightnesses. The researchers averaged the results from two different calibration schemes to get a distance of 27,000 light-years plus or minus a few thousand light-years.



DEATH THROES. A superhot white dwarf star (the dot at the center) is surrounded by a planetary nebula in this new false-color Hubble image. When the star was still a red giant, it gently hiccuped gas into space episodically, forming the concentric shells surrounding the nebula. Right before the star died, it rudely belched its outer gas layers into space, which now form the bright inner region of the nebula. This stellar mausoleum, NGC 7027, lies 3,000 light-years from Earth in Cygnus.

Howard Bond (STScI) and NASA

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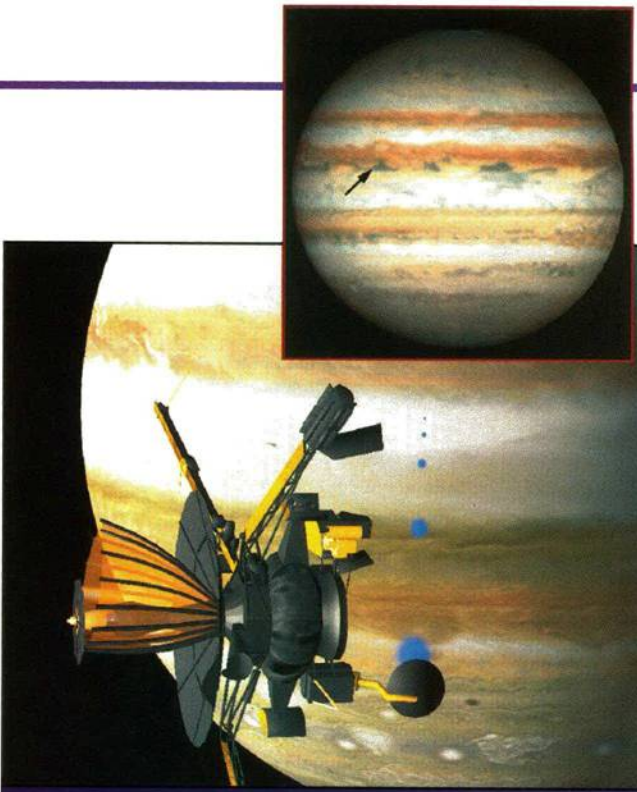
Roberta Humphreys and Jeffrey Larsen of the University of Minnesota counted stars to learn how far the Sun lies from the galactic plane. Using 12 Palomar Sky Survey fields (six each at the north and south galactic poles), they isolated over 10,000 stars with blue magnitudes between 15 and 18 belonging to the disk of the Galaxy. They report in the November 1995 issue of *The Astronomical Journal* that they found 5,383 stars in the south galactic pole fields compared with 4,849 in the north galactic pole fields. Using a simple model, this ratio yields a distance of 67 light-years north of the Galaxy's plane, give or take 11 light-years.

Multiple Impact on Earth by Asteroid or Comet String?

A line of eight circular geological features that stretches from southern Illinois to eastern Kansas may mark where a fragmented comet or asteroid struck Earth roughly 320 million years ago, say planetary scientists Michael Rampino and Tyler Volk, both of New York University.

The structures they mapped range in diameter from about 3 kilometers to 17 km, and all have ages between 330 and 310 million years. Once thought to be born in some unknown volcanic mechanism, the craters (according to Rampino and Volk) actually show signs of an impact origin. These include central uplifts, highly shocked quartz grains, and extensive shattering of local rocks.

Rampino and Volk calculate that the unusual alignment, some 700 km long, has only about one chance in a billion of being accidental. They believe that the chain was created by the impact of an asteroid or comet broken up by terrestrial or lunar tidal forces. Comet Shoemaker-Levy 9 was one example of such an object, and similar chains of craters exist on Jupiter's satellites Callisto and Ganymede and on Earth's Moon.



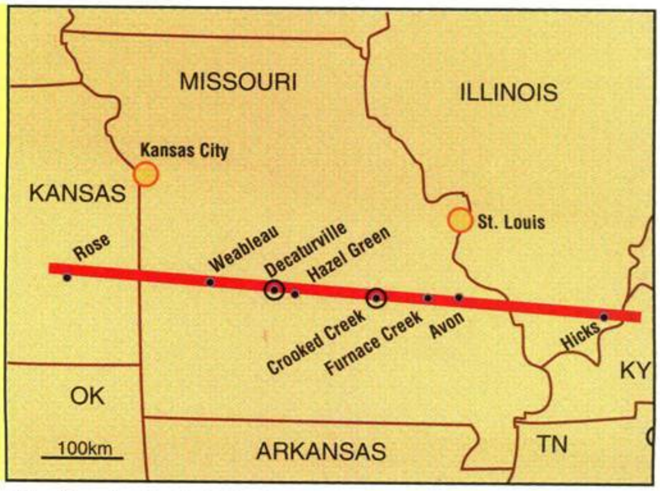
Reta Beebe/NMSU, and NASA

NASA

THE GALILEO SPACECRAFT reached Jupiter on December 7, 1995, dropping its probe into the giant planet's dense atmosphere. These images show the craft orbiting Jupiter and receiving radio signals (blue dots) from the probe, and the approximate area on Jupiter of the probe's entry (arrow in inset). See page 42 for a full report on early results from the Galileo mission.

Rampino and Volk reported on their work at a meeting of the American Geophysical Union in December 1995.

CELESTIAL MACHINE-GUN? Did a broken comet or asteroid stitch a string of craters across North America about 320 million years ago? Researchers have found a line of probable impact craters running from southern Illinois across Missouri and into eastern Kansas. The craters vary in size, but have virtually the same age and may have formed in a single event.



Michael Rampino, New York University

Next Stop, Comet Wild

Thanks to a NASA decision made last autumn, scientists should soon have material from both interstellar space and a comet. If all goes according to plan, a spacecraft called Stardust will be launched in 1999 to capture samples of periodic Comet Wild 2 along with dust streaming into our solar system from interstellar space. Stardust will then return the samples to Earth in January 2006 for detailed laboratory study.

During its December 2003 comet flyby, the craft will transmit detailed images with ten times the resolution of Giotto's snapshots of Comet Halley's nucleus taken in 1986. It also has the ability to analyze samples while in flight with a German-built mass spectrometer.

"This is really a breakthrough mission," says

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M27. *Tricolor CCD image taken with a Celestron C-8 at f/6.3 with an ST-7 CCD imaging camera and CFW-8 Color Filter wheel. Courtesy Benoit Schillings, Los Altos, California.*

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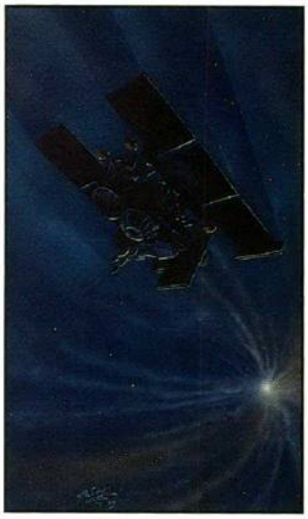
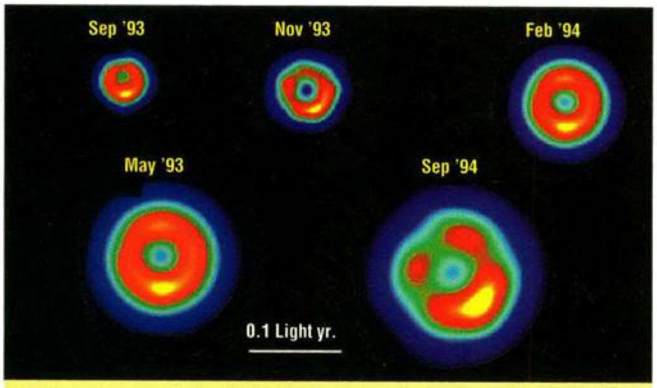
Stardust scientist Ben Clark. "It's the first sample return mission since Apollo brought rocks back from the Moon in the early 1970s, and it's our country's first robotic sample return mission."

Stardust was chosen from a field of several competitors as the fourth in NASA's series of Discovery flights, missions designed for low cost and high science return (See "New Discoveries on the Horizon," November 1995). Other Discovery missions include the Near Earth Asteroid Flyby (see "Far Journey to a NEAR Asteroid," March 1996), which launched in February, Mars Pathfinder, which launches in December, and Lunar Prospector, scheduled for arrival in 1997. — *Michael Carroll*



Michael Carroll

PEERING FROM BEHIND A SHIELD, Stardust snaps pictures and gathers samples of periodic Comet Wild 2's tail during a December 2003 flyby. The cometary stuff, along with samples of dust streaming into the solar system from interstellar space, gets returned to Earth in 2006 for study.



National Radio Astronomy Observatory

R-RATED MOVIE. These frames show a scene of utter violence, the expanding shell of debris from Supernova 1993J in the galaxy M81. An international team of radio astronomers produced the movie using radio telescopes in Europe and the U.S. The gas in the shell is traveling so fast that it would take only one day to go from Earth to Saturn. Astronomers don't know why the radio signal is stronger on one side of the shell than the other. But they were able to use these images to pinpoint M81's distance: 11 million light-years, which closely matches distances obtained by other means. Caution parents: If you don't want your kids watching such violent acts, don't tell them about the following Web site: http://info.aoc.nrao.edu/.

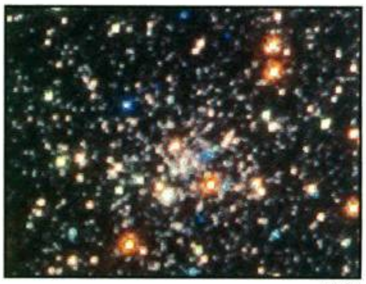
EVENT HORIZON

Son of Clementine To Scrutinize Deadly Asteroids

The Air Force Space Command is preparing a follow-up mission to last year's successful Clementine 1 Moon-mapping effort. Designated Clementine 2, the mission will deliver the first close-up look at three Earth-crossing asteroids beginning in 1998. The spacecraft will fire a single probe into the surface of each asteroid while the mothership photographs the impacts at close range. The purpose of the mission is to make a study of the composition and properties of Earth-crossers, ostensibly with the goal of developing a planetary defense against these objects.

In the Thick of Things

When the Hubble Space Telescope peered into the densest globular cluster known, M15 (below), it saw a heck of a lot of stars. Analysis of the distribution of the stars in M15 shows that at some point in the past, the stars near the center of this cluster converged on the core, like bees swarming to a hive. Hubble was called upon to help determine if the stars are packed tightly in M15 because of a black hole or the mutual gravitational attraction of so many stars in such a small volume of space. Results are forthcoming.



NASA

Most Massive White Dwarf Known

A team of astronomers at the University of Leicester in England has discovered the most massive white dwarf star known. Weighing in at 1.35 solar masses, the star, designated RE J0317–853, is very close to the 1.4-solar-mass cutoff, known as the Chandrasekhar limit. Stars more massive than this are destined to collapse further, becoming either a neutron star or a black hole. Astronomers expect the white dwarf to test the limits of the Chandrasekhar limit and stellar evolution theories.

Colliding Black Holes

Question: What do you get when two giant black holes collide? Answer: A bigger black hole. At least, that's the prediction made by a new computer model developed by theorists from Cornell University, the University of Illinois at Urbana-Champaign, the University of Texas at Austin, Washington University, and the University of Pittsburgh. Using the world's fastest supercomputers, the team created the program to see how Einstein's equations of general relativity would describe such a merger.

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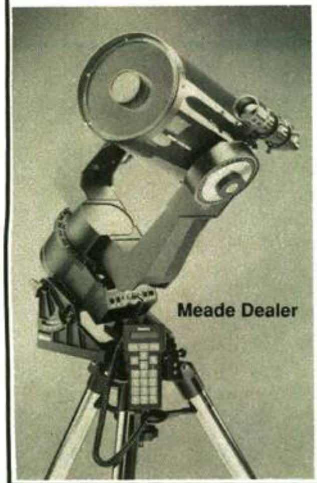

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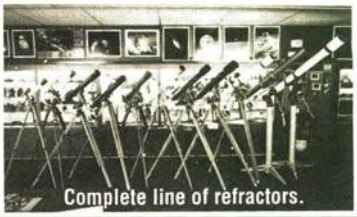

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AMATEUR NEWS

CCDs Front and Center

Sometimes it's useful to look back over the route traveled before continuing a journey. That metaphor best sums up Imaging the Sky '95, a conference that attracted more than 100 astrophotographers to Western Oregon State College on October 13 and 14, 1995. Attendees listened to talks on astroimaging's varied present and promising future, thanks to the CCD camera's potential.

Southern California astrophotographer Brad Wallis lead off with a discussion of conventional film's unbeatable track record, especially that of black-and-white Tech Pan 2415. He compared a CCD's sky coverage with that of a medium-format camera. Even the largest chips cover less than 10 percent the area of a 2 ¼" by 2 ¼" piece of film.

Serving to counter Wallis' broad indictment was Greg Bothun, staff astronomer at the University of Oregon's Pine Bluff Observatory. After acknowledging the expense of owning a CCD, he explored the CCD's potential compared to what film provides. "Where film is less than 7 percent efficient in collecting light, CCDs boast quantum efficiencies above 90 percent," explained Bothun. CCD chip engineer Morley Blouke pointed out that the next generation of chips promises to be bigger and more sensitive to a wider range of light.

Discussion also centered on using CCDs in the field. Astrophotographer Wayne Johnson told how he uses his camera to confirm supernovae in other galaxies. Don Parker was on hand to share his latest planetary photography. "Save everything you shoot," Parker advised his audience. "You never know what lies hidden in even the crummiest of pictures." As an example, he showed a dark marking on Mars he originally thought was an artifact from image-processing. The picture latter confirmed a new feature discovered by a Japanese astronomer.

ASTRONOMY: Richard Berry

PANELISTS AT A ROUNDTABLE DISCUSSION field audience questions during a session at Imaging the Sky '95. Queries ranged from tips on how to control dark current noise in a CCD camera to how the media popularizes astronomy through pictures.

ASTRONOMY associate editor John Shibley challenged conferees to go beyond "everyday" imaging. He urged amateurs to search for elusive Kuiper Belt objects, patrol the atmospheres of outer planets, and look for the faint flickerings of Cepheid variable stars in nearby galaxies. All these projects would be in the spirit of a "science safari."

For information about next year's ITS conference, contact the Rose City Astronomers, c/o the Oregon Museum of Science and Industry, 1945 SE Water Avenue, Portland, OR 97214-3354.

The Other Star Party in Texas

Amateur astronomers in central Texas gathered at Pedernales Falls State Park last October 20 and 21 for the fall occurrence of the Central Texas Star Party (they also meet in late spring).

Hosted by the Austin Astronomical Society, CTSP attracted over 100 amateur astronomers and astronomy enthusiasts to a beautiful state park along the Pedernales River, some 40 miles west of Texas' capital city.

An autumnal cold front Thursday evening briefly whisked away the ever-present Texas humidity, creating transparent skies both Friday and Saturday nights.

The showcase object of both nights was Comet Schwassmann-Wachmann 3. A month past peak brightness, this comet was visible for only a couple of hours before setting. David Sands' Meade 8-inch LX-200 showed a bright, splayed dust tail and a narrow ion jet.

Jim Walker brought his 17-inch Dobsonian to bear on such objects as the Helix and the Dumbbell Nebulae, both of which presented textbook images. By far the most impressive object in Walker's telescope — which he purchased in a pawn shop! — was the Veil Nebula. Even without a high-contrast filter, the filamentary texture was quite evident.

Telescope builder and optician Larry Forrest suggested viewing the Veil using high-contrast filters and 11x80 binoculars. The combination produced an outstanding and unique view of the entire nebular complex.

The star party was presided over by Austin Astronomical Society president Kelley Knight, who took time to explain a little about the society's planned observatory. The telescope structure, a split-roof, 560 square-foot building with adjacent parking for 50, will cost somewhere between $25,000 and $30,000.

The next Central Texas Star Party is scheduled for June 14 and 15 at Pedernales Park. For more information, call Kelley Knight at (512) 447-1163. □

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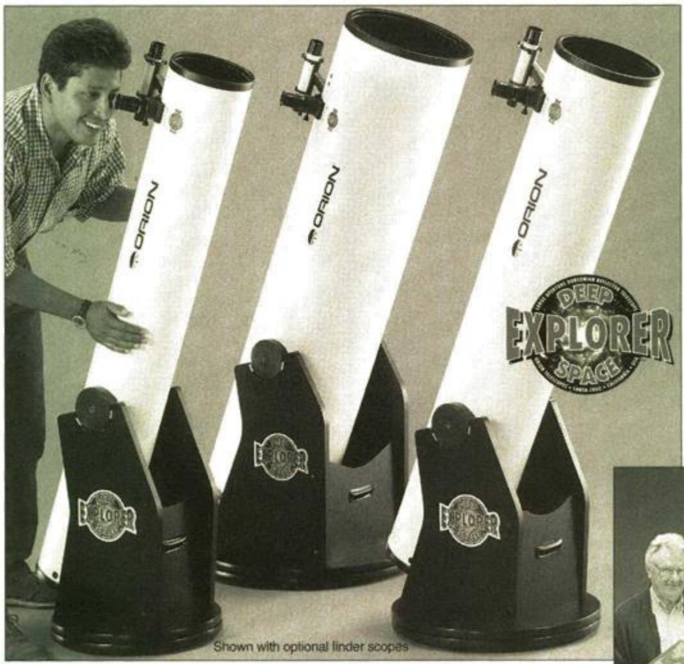

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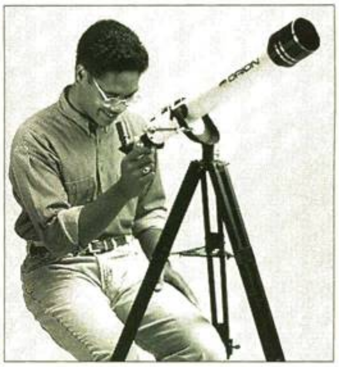

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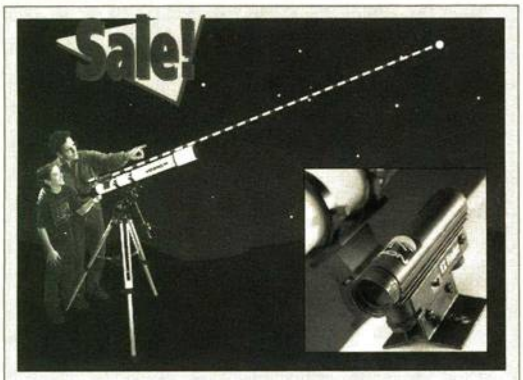

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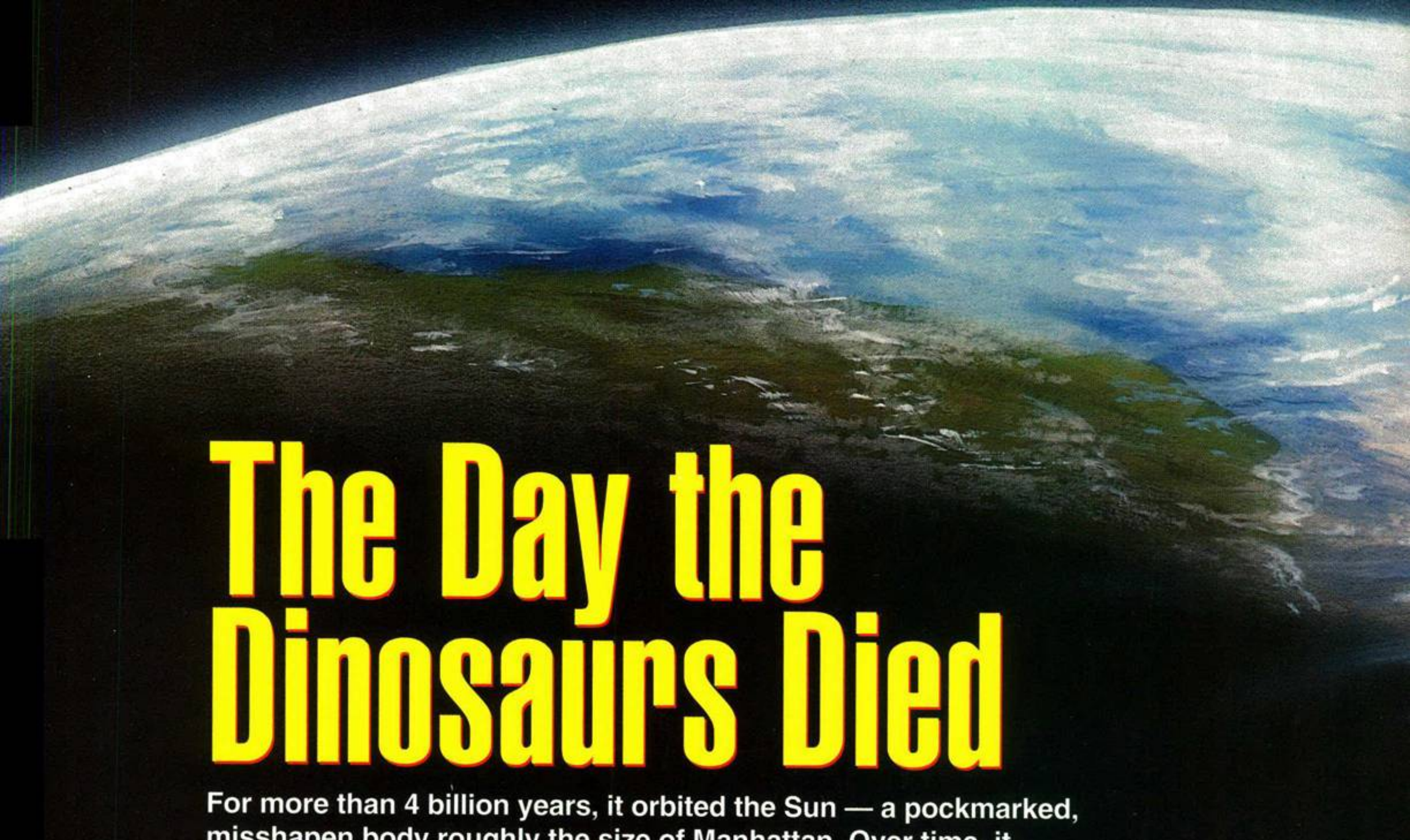


The Day the Dinosaurs Died

For more than 4 billion years, it orbited the Sun — a pockmarked, misshapen body roughly the size of Manhattan. Over time, it wandered into the inner solar system, occasionally passing near our planet as it journeyed around the Sun.

Then, one day about 65 million years ago, Earth and the rough-hewn body reached the same place at exactly the same time.

by Ron Cowen

The solar system is a hazardous place. Countless fragments of rock and ice tumble about in orbits that occasionally produce impacts on planets. Most of the time these are minor events. Once in a great while, they are catastrophic events, affecting planets as a whole and leaving long-lasting effects. The most famous large impact on planet Earth, the one the killed the dinosaurs, is now coming into clear focus.

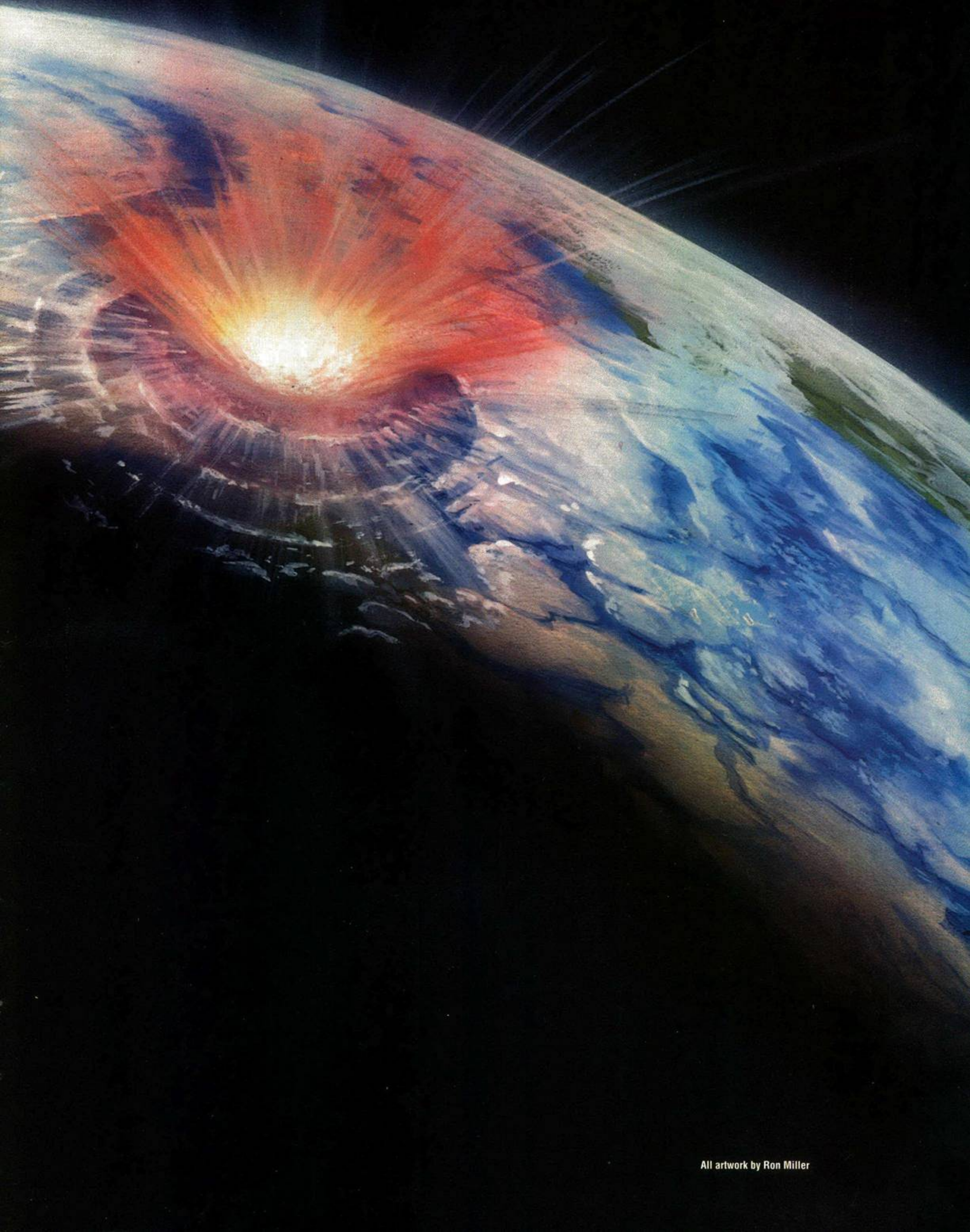
After 15 years of fractious debate, most scientists now agree that an asteroid or comet collided with Earth 65 million years ago. Most of the nonbelievers threw in the towel in 1991 when scientists discovered the smoking gun for the impact — a vast, buried crater in the Yucatan Peninsula. Known as Chicxulub (CHEEK-shoe-lube), a Mayan word that ironically means "devil's tail," this huge hole was formed during the interval of geologic time known as the K-T boundary, which marks the end of the *Cretaceous* (K) period and the beginning of the Tertiary (T). (See "Tracking Down Chicxulub," p. 35.)

But if there's consensus that a huge object smacked into Earth, critics have found another battleground. A catastrophic solar system impact has leaked into other fields as geologists, paleontologists, astronomers, and atmospheric scientists debate exactly how lethal the long-ago collision was, and which of its many aftereffects proved most deadly.

Before the impact, dinosaurs still roamed Earth and numerous species of phytoplankton — which serve as food for tiny sea animals — filled the oceans. A geologically short time later, the last dinosaurs had gone belly up, along with two-thirds of all living species.

Was the K-T impact entirely responsible? And if so, exactly how did it exert its lethal influence?

To understand the K-T impact, scientists are drawing on their knowledge of all solar system impacts. "The ramifications of a large impact are still poorly understood," note planetary scientists Owen Toon and Kevin Zahnle of NASA's Ames Research Center in Mountain View, Calif.



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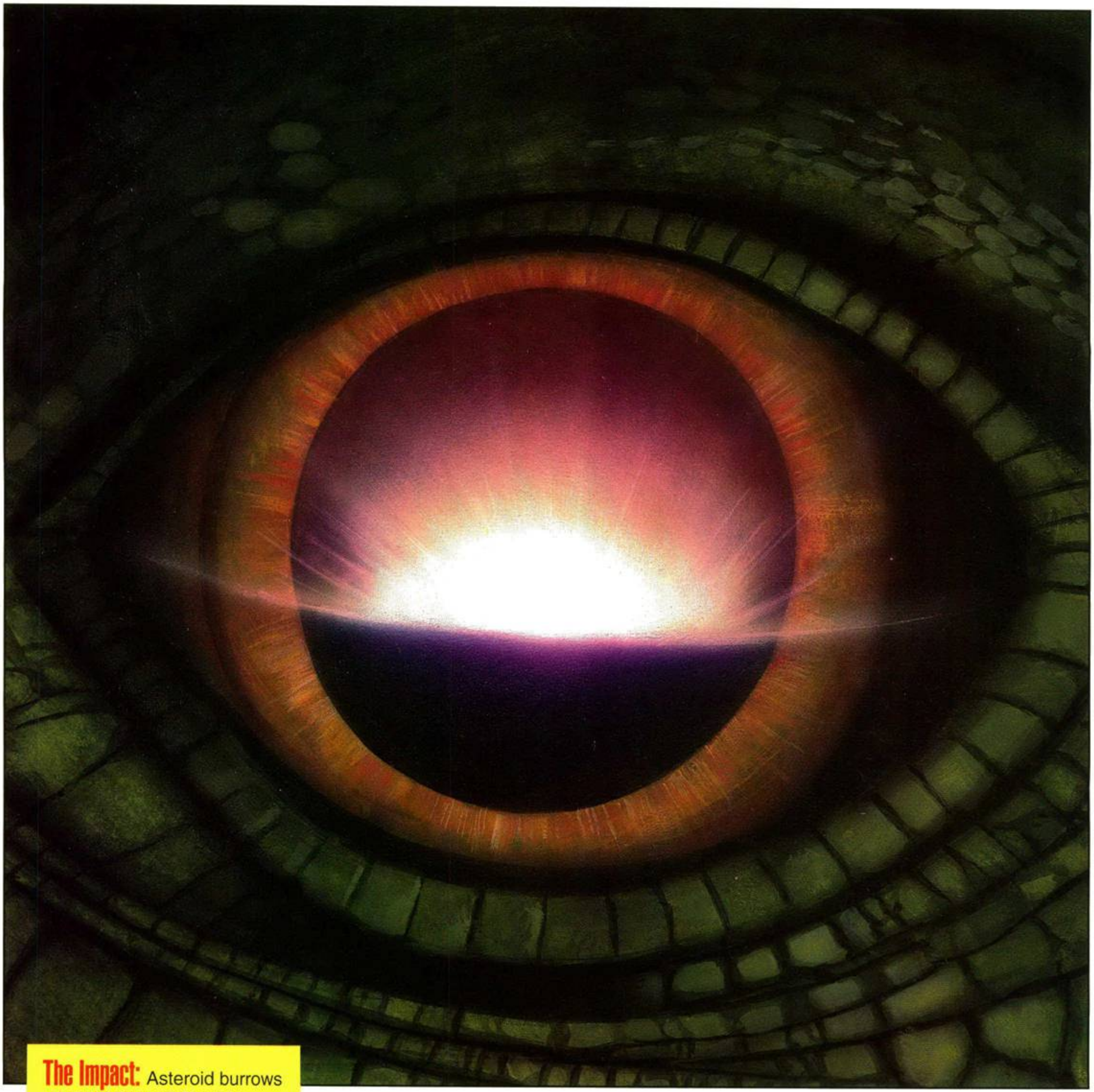


The Impact: Asteroid burrows a tunnel through Earth's atmosphere and smashes into what is now the Yucatán Peninsula. Everything in the immediate area is devastated; all other life on Earth will shortly feel the impact in other ways.

Says Buck Sharpton of the Lunar and Planetary Institute in Houston: "The focus here is to try to understand how you can have an impact event [that was so catastrophic]. Bear in mind that we always thought that a [comet or asteroid] would deposit most of its energy right at ground zero. So how can it, as energetic as it was, cause a global extinction? It had to wipe out just about everything."

"It's not so much that the impact itself was so lethal," agrees paleontologist Peter Ward of the University of Washington in Seattle. "It squashed a few moths, a few this and a few that. That's not what killed everything."

"My own philosophy about the K-T impact is that everybody wants to discover the one thing that killed the dinosaurs," says Toon. "But the fact is it's a very complicated situation, in which multiple things happened. It's not like everything died from one cause."

Chronology of a Catastrophe

A grand planetary impact is an amazingly destructive thing. Imagine the energy unleashed if the entire world's arsenal of nuclear weapons suddenly exploded. Now multiply that by 10,000. The blast, equivalent to 10 trillion megatons of TNT, is only a conservative estimate for the destructive force generated by the smash. Here's the chronology of the catastrophe, according to Toon and several other scientists.

Time zero: As the object cannonballed through Earth's atmosphere, it generated a shock wave that blew a hole in the air.

Seconds to first hour: Reaching the ground about three seconds later, the bolide plowed through a 1 kilometer-deep ocean and into Earth's crust, generating earthquakes at every exposed fault line over the next few hours. Within the first hour of impact, 100-foot-high walls of water — ocean waves from what is now the Gulf of Mexico — flooded coastal plains. But these were only the local effects, devastating just a few percent of Earth's surface. Minutes after the impact, billions of tons of debris blasted into space, three to four times the mass of the bolide. Rocketing upward and outward at speeds nearly great enough to escape Earth's gravity, the dusty debris reentered Earth's atmosphere far from the site of the impact with a vengeance, reheating and glowing red-hot.

For 30 minutes to an hour after the impact, "the entire sky was like a big, glowing sheet of rock," says Toon.

"Imagine the effects of a thousand shooting stars suddenly entering the atmosphere and ablating at an altitude above 60 km. The sky would turn from its normal transparent blue to a brilliant red sheet of glowing lava," note Toon and Zahnle.

Toon adds, "The shooting stars wouldn't have hit you; they stop at 60 km or so above the ground. But there's so many of them that you're standing there in this radiation bath, hot enough to set paper on fire.

The collision of Comet Shoemaker-Levy 9 with Jupiter drove this point home, several scientists assert. Fragments of the comet no bigger than half a kilometer in diameter — far smaller than the size of the impactor that created Chicxulub — produced a plume of debris that reached 5,000 kelvins.

More to the point, the hot plume splashed down over an area on Jupiter that exceeded that of Earth.

"Comet Shoemaker-Levy 9 provided proof that the K-T impact ignited global fires and scorched Earth," says Jay Melosh of the University of Arizona in Tucson.

"The bigger animals would have been broiled in their tracks," he notes. But, says Toon, some organisms that had natural shelter might still survive. "If you're a crocodile underwater — no problem. If you're a mouse in your hole — no problem."

From the first hour to six months: After an hour or so, according to Toon and Zahnle, the red sky would cool and blacken. By the end of the first day, soot from charred debris would block out the Sun, plunging the world into darkness for as long as a year.

Six months to a decade: Sulfur ejected into the stratosphere by the impact and slowly converted to sulfuric acid, a highly efficient Sun blocker, may have prolonged the blackout for as long as a decade.

"The fires themselves wouldn't have killed ocean life, but if you turn the lights out, phytoplankton stops reproducing and you trigger the collapse of the ocean

Tracking Down Chicxulub

It all began in 1978 when Walter Alvarez, a geologist at the University of California, Berkeley, returned from a field trip to northern Italy's Apennine Mountains. Near the town of Gubbio, he had collected some 400 pounds of rock from a curious, pencil-thin layer of gray clay. Like a bookmark, this layer seemed to indicate the boundary between the end of the Cretaceous period and the beginning of the Tertiary.

Alvarez's father, Nobel Laureate physicist Luis Alvarez, suggested he measure the amount of iridium, a member of the platinum group of elements, in the clay layer. Iridium is common in comets, asteroids, and meteorites, but exceedingly rare in Earth's crust. Thus, a substantial amount of iridium might mean that many small meteorites had the chance to bombard the boundary layer, an indication that the layer lasted for an extended time.

To their astonishment, the scientists found that the clay contained 30 times more iridium than the gradual deposition of micrometeorite dust could account for. Berkeley researchers Luis Alvarez, Walter Alvarez, Frank Asaro, and Helen V. Michel proposed an alternative explanation. They suggested that a large meteorite, roughly 8 kilometers in diameter, had smacked into Earth 65 million years ago, carrying with it some 200,000 tons of iridium.

But a key piece of evidence was still missing. If a huge bolide had indeed smacked into Earth, where was the hole? "The biggest string that was left untied for a long time was the question of where the crater is," says Walter Alvarez. It was a question, he notes, that had haunted him and his colleagues ever since they reported their initial findings in 1978.

Unknown to geologists, evidence had been slowly mounting for more than two decades that an area on the northern coast of Mexico's Yucatán Peninsula might contain the telltale crater. During the 1950s, the Mexican national petroleum company, Pemex, discovered an unusual layer of broken rocks and structure while drilling in the region. A magnetic survey commissioned by Pemex later revealed a large circular structure at the site, centered near the town of Chicxulub. In 1968 and 1972, two geologists suggested the region represented a large buried crater.

By 1991, several other researchers, including Kevin O. Pope of Geo Eco Arc Research in La Canada, Calif., Adriana Ocampo of JPL, and Charles Duller of NASA's Ames Research Center, had also published reports affirming the impact origin of the Chicxulub site."Now there really is very little doubt that the impact site is in the Yucatán Peninsula," says Walter Alvarez. "I think that basically wraps up the biggest question about the whole thing."

ecosystem," Toon notes.

Without sunlight, temperatures on land would take a nosedive — a far larger drop than Earth endured during the Ice Age. Global cooling may have lasted for a decade.

A decade after the hit: Following the cooling came the warming. The collision may have squeezed carbon-containing material out of rock at the impact site, creating a blanket of carbon dioxide in the atmosphere. This greenhouse gas would have heated Earth for 50 to 100 years, according to Toon. At first, he notes, the oceans would have soaked up some of the excess carbon dioxide, but their capacity would soon have been overwhelmed by the concentration in the atmosphere. Temperatures would rise for up to a century, Toon conjectures. "Temperatures don't just go back to normal after the global cooling but rise considerably higher," notes Sharpton. "There's a shift in temperature and it stresses the heck out of things. You might just be getting used to the cold and all of a sudden you've got this hot dry spell."

However, not all scientists agree on this warming. Kevin Pope of Geo Eco Arc Research in La Canãda, Calif., feels the warming would be negligible. "Recent research has shown that climate warming due to greenhouse effects from carbon dioxide released by the impact was extremely minor," says Pope. He is not alone: Studies by Thomas Ahrens of Caltech suggest the same result.

The Rock Hits the Powder Keg

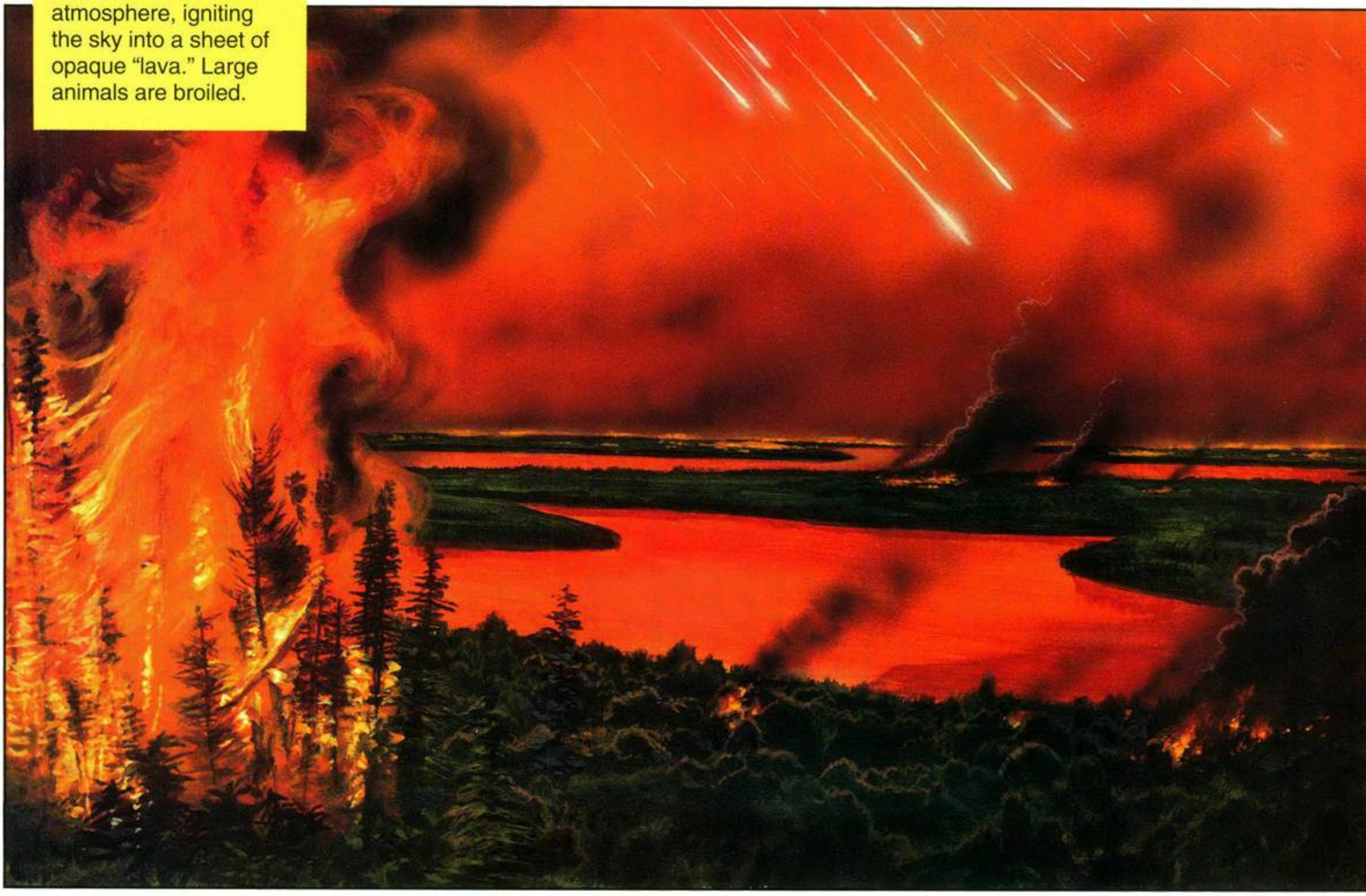
The sheer size of the impactor — estimated to be 10 km in diameter — can't by itself account for the devastation. Haraldur Sigurdsson of the University of Rhode Island and other researchers believe that the impact sounded the death knell for so many species because of the unique composition of the crash site.

Several lines of evidence reveal that the bolide hit a sulfur-rich region of the Yucatán Peninsula, kicking up billions of tons of the element. "We think the severity of the event relates to the unusual chemistry of the terrain where the impact occurred," notes Sigurdsson. "The bolide hit the powder keg when it struck this chemical sediment."

He and his colleagues had found that the target rock in the Yucatán includes a 3-km thick sequence of carbonites and evaporites. Evaporites include gypsum and anhydrites, forms of calcium sulfate that contain large concentrations of sulfur.

Unlike soot and smoke, which probably washed out of the lower atmosphere in six months, the sulfur dioxide spewed into the upper atmosphere and lingered there for several years. The globally dispersed

Seconds to an Hour: Earthquakes and walls of water swell from the impact point, but the real devastation comes from fiery hot debris falling back into Earth's atmosphere, igniting the sky into a sheet of opaque "lava." Large animals are broiled.



sulfur dioxide does not readily undergo chemical reactions and, because it is a gas, it does not settle out quickly like soot and dust.

By itself, sulfur dioxide doesn't do much damage. But ultraviolet sunlight and the presence of water eventually transform it into sulfuric acid. This falls to Earth as a toxic rain as corrosive as battery acid. "Unlike the aftermath of typical impacts, the skies remained murky for at least a decade due to chemically generated clouds of sulfuric acid high in the stratosphere," says Kevin Baines of NASA's Jet Propulsion Laboratory.

Baines and other team members led by Kevin Pope comprise an interdisciplinary group that is combining computer models of the Chicxulub impact and its atmospheric effects with geological studies of the crater.

Baines notes these same atmospheric conditions occur on Venus, which is perpetually cloaked in sulfur clouds. "The entire ecosystem of Earth, including plants and animals, was subjected to extreme environmental conditions for more than a decade. This Mother of all Environmental Disasters was simply too much for a large number of well-established species, such as the dinosaurs, to cope with," he says.

But Toon strikes a cautionary note. "The soot is in the K-T boundary layer, so you know that happened; we had to burn the entire world's biomass to have the amount of soot observed in the boundary layer," he says. In contrast, "We don't actually have any direct evidence that the sulfur did anything in the boundary layer."

"I would not bet my life on the contribution of sulfur to this whole business," says Peter Ward. "Sulfur is the least reliable kill mechanism we have in the sense that there is so much leeway, a lot of sway in the numbers. Dust going up in the atmosphere could have been every bit as catastrophic as the sulfur emissions. Several analyses suggest that when dust goes up, it perturbs rainfall cycles. Immediately after the K-T impact, places that had been previously wet became dry and those that were very dry became wet."

Despite the feelings of Toon and Ward, many scientists remain skeptical of the sulfur story and research continues, but evidence is mounting that a decade of cooling may have contributed to the dinosaurs' demise.

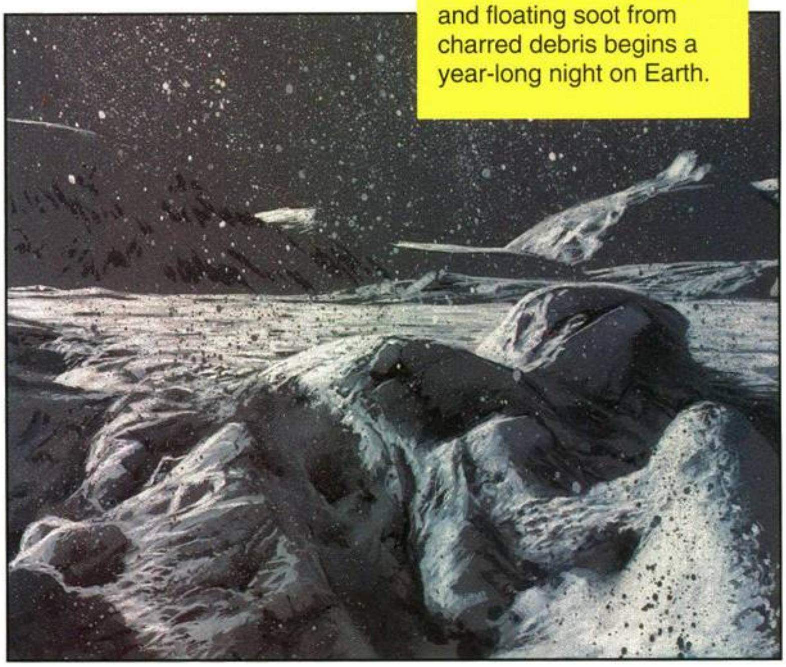
To Kill the Dinos or Not to Kill?

Some researchers consider micropaleontologist Gerta Keller of Princeton University a stubborn holdout. She has coined her own phrase for the true believers in the K-T catastrophe: "impact diehards."

It's largely physicists, astrophysicists, and chemists, she contends, who support the theory. "Relatively few paleontologists believe the impact can snuff out life; they just don't see that in the data. Dinosaurs were already in decline the last few million years of the Cretaceous period," Keller adds.

Keller says she does agree with other scientists that because dinosaur bones are scarce these fossils can't provide a detailed record of what happened 65 million years ago. "The best information is from the bottom of the food chain," she says, in part because such primitive organisms as pollen grains and fungal spores are plentiful and well preserved in sedimentary rocks.

Among the most abundant inhabitants of the sea is foraminifera, a type of plankton supposed to have suffered nearly complete extinction according to the impact theory, Keller says. These single-celled organisms live in the upper 100 to 400 meters of the ocean, and in the tropics they did indeed disappear quickly at the K-T boundary, she adds. But at more northerly and more southerly latitudes the die-off is considerably less severe. "Basically what paleontologists see is a differential pattern of extinction," Keller notes.



An Hour to Six Months: After an hour the red sky darkens into blackness, and floating soot from charred debris begins a year-long night on Earth.

"The impact diehards don't like this," she asserts. "They predict that effects of such an impact must be global, extinction must be global, and there must be no differential across latitudes."

Pope, however, replies, "The fact is, such a latitudinal gradient, with most extinctions occurring in the tropics, is exactly what is to be expected from impact-induced global cooling and blackout because high-latitude species are better adapted to cold and low light levels."

Paleontologist Ward concurs that extinctions were not as great at the poles. "The high latitudes in all probability served as a refuge; plant extinctions were definitely not as severe at high latitudes." However, he adds, such limited protection in no way mitigates the global influence of the K-T impact.

Says Ward: "Even in a severe forest fire, there are always pockets of unburned material and pockets of survivors; it's very difficult to eradicate everything. But all the evidence points to a catastrophe."

Ward notes that for several years he, too, didn't buy the impact story. After all, the marine mollusks he studied appeared to have died off gradually rather than suddenly, in direct contrast to the effect of a large impact. Working with Charles Marshall of the University of California, Los Angeles, Ward subjected fossils found at various layers in the Cretaceous and Tertiary periods to a new statistical analysis. The researchers found that "in almost all cases, the big fossils all show a sudden extinction at the K-T boundary — even though the actual pattern in the rock record looks anything but sudden," says Ward.

"The bigger the fossil, the rarer they are, and the less chance you have of finding the last one right at the K-T boundary. So the dieoffs look gradual, but they're really not. A catastrophic extinction will always look gradual for big fossils because there are so few of them and because paleontologists have trouble finding them."

Ward says that several paleontological mysteries remain. "We want to know why some plankton go extinct and why others do not. The easy answer is that deep plankton survive the blast best, overwintering deeper in the ocean until the atmosphere warms."'

Subtle Evidence for the Big Smack

But that type of easy answer isn't what Jablonski and University of Chicago paleontologist David Raup discovered when they examined the survival of 350 evolutionary lineages of marine bivalves — clams and other two-shelled ocean dwellers — at the time of the Cretaceous period. Based on the rich, well preserved fossil record of these at the K-T boundary, the researchers find that the normal rules of evolution simply didn't apply. Mass extinctions wipe out all types of bivalves, without regard to special survival strategies developed during other, less violent times, the paleontologists conclude.

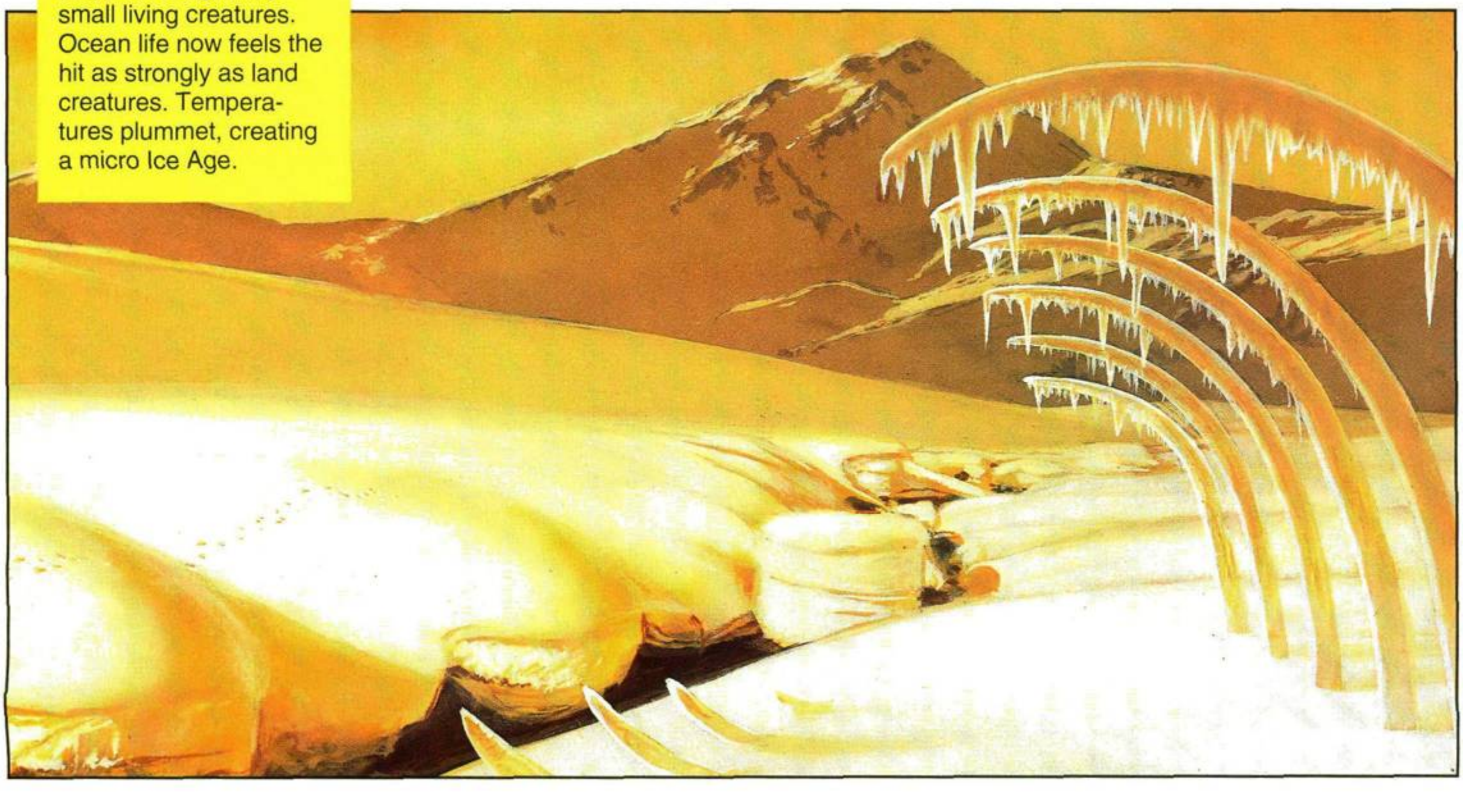
Raup and Jablonski also uncovered one factor that seemed to enhance survival. Those organisms distributed over many continents had a higher survival rate than those that had a narrow geographic existence. One intriguing notion, he muses, is that "maybe this change in the rules for extinction or survival helps explain why the dinosaurs are gone and mammals weathered the extinction at the end of the Cretaceous." This could "open the door to a whole new way of looking at mass extinction as an evolutionary force."

Comet or Asteroid?

Scientists continue to debate whether the huge impactor was an asteroid or a comet. Sharpton argues that it was probably a comet. "The materials in the K-T boundary suggest that the impactor is primitive, undifferentiated material," Sharpton says. This suggests the possibility that it was a comet." He adds that the estimated size of the bolide, about 10 km, also makes a cometary source more likely.

On the other hand, he notes, "we have a lot of these objects in our vicinity called near-earth asteroids. So we can't eliminate the possibility that it was an asteroid." (See "Far Journey to a NEAR Asteroid," March 1996.) Geologist Eugene Shoemaker of Lowell Observatory in Flagstaff, Arizona, says he's puzzled by

Six Months to a Decade: Sulfur thrown into Earth's atmosphere converts to a sulfuric acid rain, blocking out the Sun for several years and poisoning many small living creatures. Ocean life now feels the hit as strongly as land creatures. Temperatures plummet, creating a micro Ice Age.



another mystery. According to Shoemaker, two distinct layers of material are associated with the K-T impact — created apparently by two distinct episodes of deposition, separated perhaps by a growing season.

"The serious problem is that we do not understand how those two layers formed. Along with shocked quartz, there is shocked zircon in the upper layer. Other people have glibly said, 'Oh well, the lower layer is the fallout layer, the upper layer is the fireball layer.' Well, that's bull. The lower layer is just as much the fireball layer as the upper."

Says Pope: "The best explanation for the two-part stratigraphy is that the lower unit, which contains very little shocked quartz (tiny crystal grains fractured by the impact) and lots of microtektites, was deposited ballistically on relatively short trajectories that did not leave the atmosphere. The upper unit, with abundant shocked quartz, as well as most of the iridium, contains material that was initially ejected much higher, perhaps above the atmosphere, and settled to the ground more slowly, thus landing on top of the tektite layer."

Additionally, Adriana Ocampo of JPL and Pope recently discovered a Chicxulub ejecta deposit in Belize, only 360 km from the center of the impact. This deposit also contains two layers, the lower one with tektites and carbonate spherules, and the upper one with boulders up to 7 m across floating in mud.

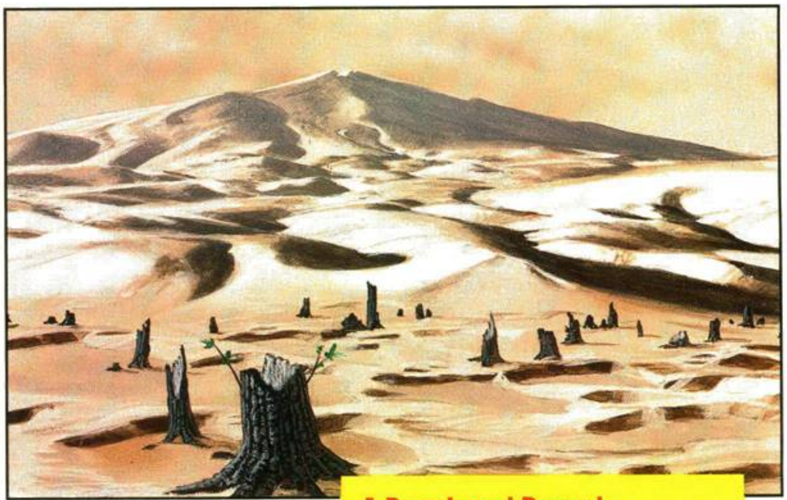
And then there's a more basic puzzle. After several years of taking gravity maps, drilling at the site, and evaluating seismic data from Chicxulub, geologists still don't agree on the size of the crater. Sharpton and his colleagues assert that it has a diameter of about 280 km. "Any estimate less than 200 kilometers is bordering on nonsense," Sharpton declares. A recent study of the topography of the northern Yucatán by Pope and his colleagues found several concentric troughs and ridges that also indicate that the crater is larger than 200 km in diameter (they suggest 240 km).

Yet Alan Hildebrand of the Commission Geologique du Canada and his team claim just as loudly that the crater is no more than 180 km across. At stake are estimates of the energy and mass of the impactor, properties directly linked to the diameter of the crater it gouges.

"It may seem strange that experts cannot agree on something so basic as the size of an impact crater," concedes Melosh in a commentary in the August 3 *Nature*. However, he notes, "the problem is that the structure of all craters is not the same and the relation of the final crater form to the impact that created it is often unclear."

The initial cavity gouged by an impactor, dubbed the "transient crater," collapses immediately under the influence of gravity to form one of a variety of crater types. And therein lies the challenge. "It is really the transient crater size that matters in deducing impact energy, and so the problem is to relate the measures of crater diameter to the crater size," Melosh says.

Determining the diameter of the Chicxulub crater poses further difficulties, he notes, because the crater lies buried under as much as a kilometer of sediment.



A Decade and Beyond: Now carbon dioxide in the atmosphere takes over and reverses the cold, rather suddenly warming the planet for 50 to 100 years, reaching a much hotter than normal peak. If this controversial reverse in temperature occurred, the shock would have been too much for many of the living beings that survived the earlier catastrophes.

In recent studies, Sharpton and his colleagues have detected a ring-shaped feature surrounding the Chicxulub site that has a diameter of 280 km. Sharpton maintains that the ring indicates the edge of the crater and deduces that the transient crater must have had a diameter between 145 and 205 km. But using the same data set, supplemented by five new gravity maps, Hildebrand and his colleagues see no hint of Sharpton's outer ring.

With the debate about the gravity data likely to continue, Melosh suggests that geologists might rely on an alternative way of estimating the diameter of Chicxulub. In this method, researchers use the quantity of iridium scattered over Earth's surface by the impactor to determine the diameter of the body that slammed into Earth. Current iridium estimates indicate a 10-km projectile, which would gouge a transient cavity of about 70 km in diameter.

"Many opinions have been changed by the impact of Comet Shoemaker-Levy 9 on Jupiter, especially as it now seems that the largest individual fragments were only 700 meters in diameter," says Melosh. Although Jupiter's gravity caused the fragments to slam into the giant planet with a velocity of 60 km per second — much higher than in the terrestrial collision — the smaller size of the Shoemaker-Levy 9 projectiles means that the fragments carried at most one-hundredth the energy of the K-T impactor.

"Was the impact of an asteroid or comet big enough to gouge a 180-kilometer-diameter crater in the Earth also big enough to wipe out the dinosaurs?," asks Melosh. "Many people would now answer with a resounding 'yes'." ☐

Ron Cowen is a frequent contributor to ASTRONOMY. He is an editor at Science News.

Into the Maelstrom

In just 57 minutes the Galileo probe upset a lot of expectations about Jupiter.

by Robert Burnham

The spacecraft fell out of the late afternoon sky toward the streaming cloud deck. After riding a trail of ionized gas thousands of kilometers long, the craft opened its parachute, turned on its instruments, and began a controlled fall into the Jovian maelstrom. An hour later, the Galileo probe's mission was over — but the vital information about the giant planet was safely on board the Galileo orbiter for transmittal to Earth.

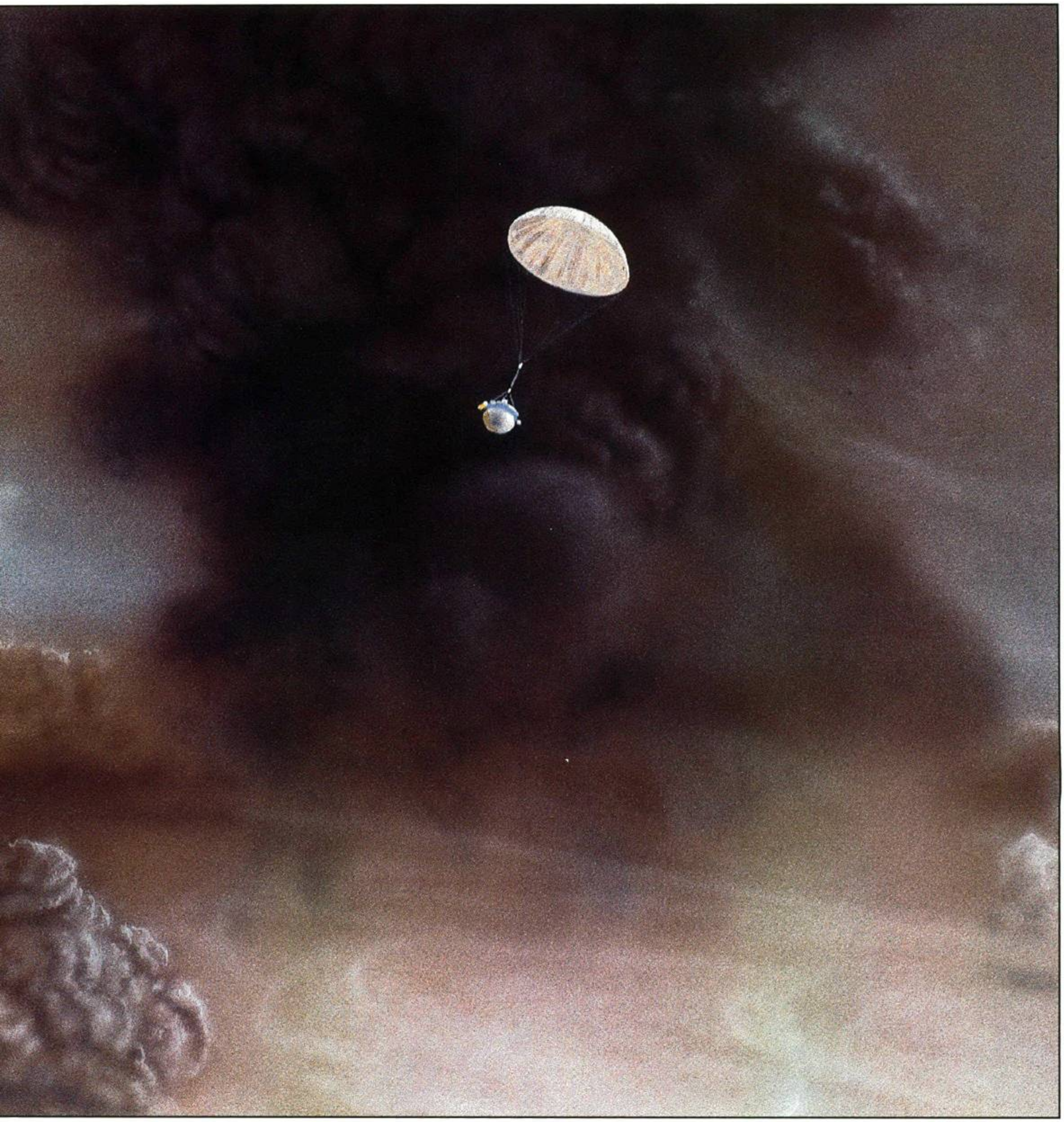
The probe's ride into Jupiter was wild and turbulent — like a plane battling through a big storm.

The Jupiter that the probe sampled on December 7, 1995, differed significantly from scientists' expectations. First, Jupiter's composition tested more like the Sun than anyone had figured. Next, not only did the entry site lack the expected three layers of cloud, but its thin clouds contained no water, which the Voyager measurements and the Shoemaker-Levy 9 impacts indicated was there. Also, lightning was relatively rare and seems to have generated no complex organic molecules. The atmosphere itself was both denser and windier than scientists had guessed, and the winds did not slacken as the probe descended. Finally, the probe found an unsuspected radiation belt extending from Jupiter's filmy dust ring down almost to its cloudtops.

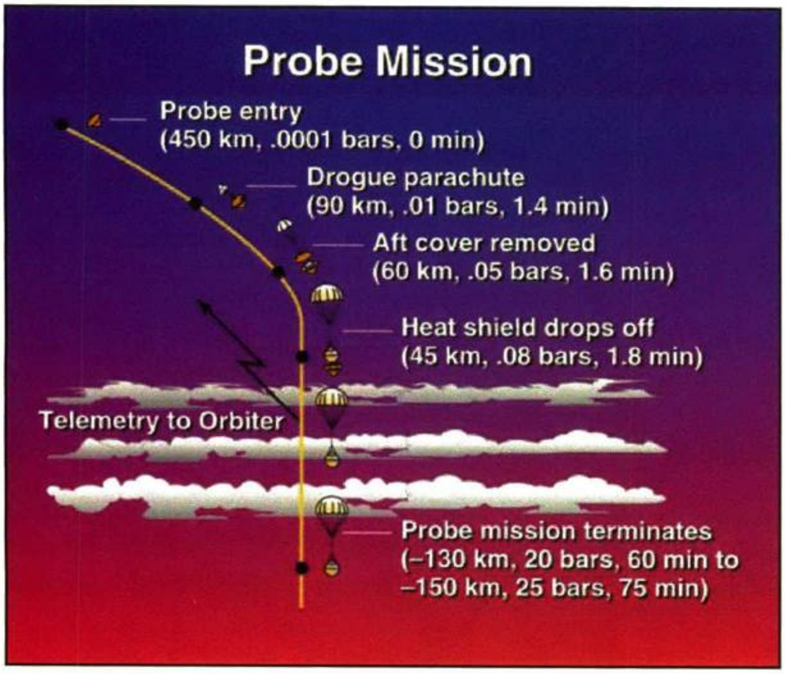
"There's always a sense of humility when the data come in," sighs Galileo chief project scientist Torrance Johnson, of the Jet Propulsion Laboratory. "The results don't fit our models very well . . . the shoe pinches!"

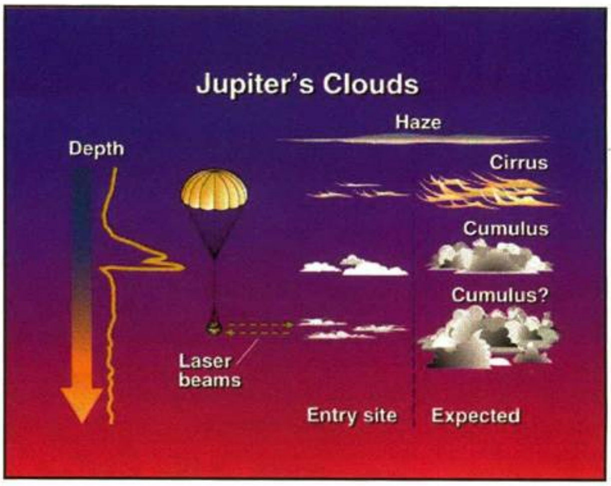
The probe had been on course for Jupiter since parting from the orbiter six months before. Its target: a spot in the Jovian clouds on the southern edge of the North Equatorial Belt, at 6.6° north latitude and 4.4° west longitude. While every

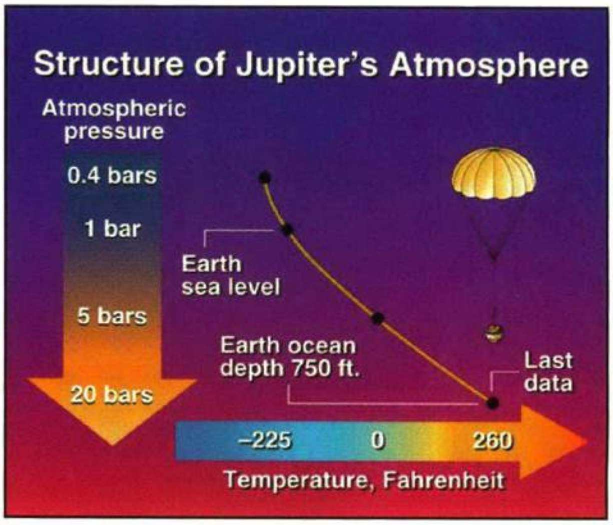
TOWERING CLOUDS DWARF the Galileo probe as it makes the first-ever descent into Jupiter. The mission findings promise to change many theories about the planet and its origin.



Ron Miller


Probe Mission
Probe entry
(450 km, .0001 bars, 0 min)
Drogue parachute
(90 km, .01 bars, 1.4 min)
Aft cover removed
(60 km, .05 bars, 1.6 min)
Heat shield drops off
(45 km, .08 bars, 1.8 min)
Telemetry to Orbiter
Probe mission terminates
(–130 km, 20 bars, 60 min to
–150 km, 25 bars, 75 min)


Jupiter's Clouds
Haze
Depth
Cirrus
Cumulus
Cumulus?
Laser beams
Entry site
Expected


Structure of Jupiter's Atmosphere
Atmospheric pressure
0.4 bars
1 bar
5 bars
20 bars
Earth sea level
Earth ocean depth 750 ft.
Last data
–225
0
260
Temperature, Fahrenheit

All diagrams, NASA

location on Jupiter is a swirling mosaic of gas, scientists chose this site because they hoped it would be as representative of the "normal" Jupiter as possible.

Jupiter's menu of surprises opened before the probe had tasted even the first wisp of Jovian air. In the hours before entry, the probe's instruments detected a new, energetic radiation belt of charged particles. "No spacecraft had ever gone inside the dust ring before," notes Richard Young of NASA's Ames Research Center, the probe's chief scientist. The new belt extends from the dust ring (at 1.8 Jupiter radii) down toward the cloudtops and is at least ten times stronger than Earth's radiation belts.

"We don't know where these high-energy particles come from," says Harald Fischer of the University of Kiel, Germany, a scientist working on the energetic particle detector. The particles reach maximum strength, he notes, about 50,000 kilometers above the cloudtops. It will take more study, and data from the orbiter, to unravel the puzzle of where the particles in the new belt originate.

Galileo's results will help scientists study all gas-giant planets — the Sun's and those that belong to other stars.

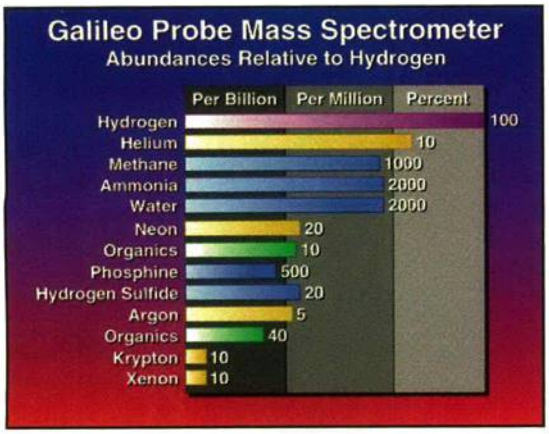
When the probe finally began its entry, the first touch of the Jovian atmosphere was lost, scientists say, because for unknown reasons the data collection began 53 seconds late. But despite this, the probe recorded another surprise: a relative lack of clouds.

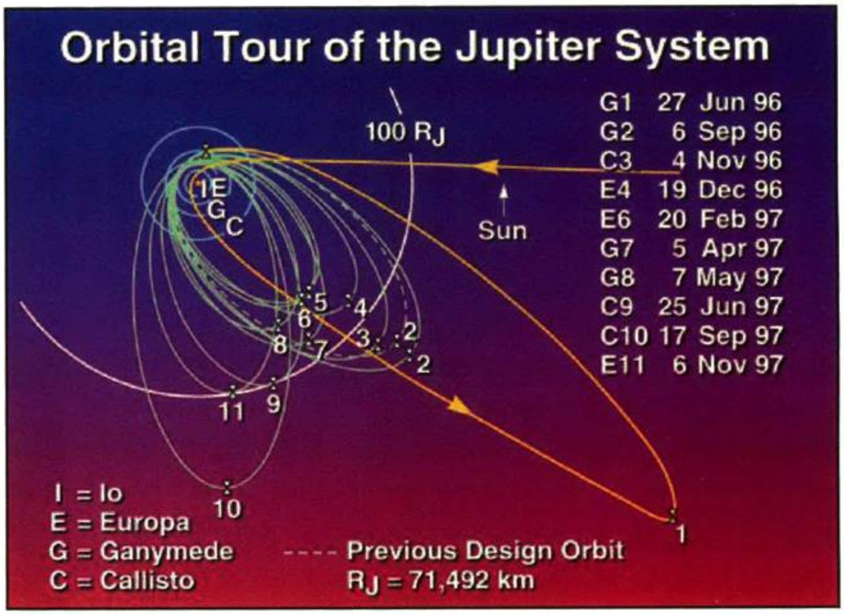
At an altitude where the pressure was about a third of a bar (1 bar = Earth's surface pressure), the probe detected a layer of what may have been thin ammonia cirrus. Its evanescent quality was unexpected. Based on models using Voyager and Shoemaker-Levy data, scientists had anticipated a thicker and denser layer here. And this pattern continued. Below the cirrus the probe found a cloud of ammonium hydrosulfide that was about as thick as light fog or mist on Earth, hardly the big piles of cumulus clouds that models had predicted. Lower still, where scientists looked to find water clouds, the probe detected nothing. Besides being almost cloud-free, the atmosphere was unexpectedly warm and completely dry, with no trace of water vapor or ice.

The lack of water was surprising, but perhaps the biggest jolt involved the composition of Jupiter's atmosphere. It contains a riddle that will worry theorists until they fully understand it.

Scientists had expected to find Jupiter enriched (relative to the Sun's composition) in water, oxygen, carbon, helium, neon, and other materials. What they got, however, was a Jupiter much more Sun-like in its makeup. And this has implications for ideas on how nature makes a Jupiter and other gas-giant planets.

Two contrasting models have sought to explain the origin of Jupiter. One says Jupiter formed from the same materials as the Sun, but stopped growing





before it could become a second star. The other model says that Jupiter formed the way Earth did — out of rocky planetesimals — but in a colder part of the solar system. Being cold let Jupiter also accrete hordes of icy planetesimals, comets and asteroids rich in carbon compounds. If the first model was right, Jupiter would be solar in composition. If the second was right, Jupiter would have extra amounts of water, carbon, and so on.

What the probe found was a Sun-like Jupiter. This poses a big problem for theorists. Why? Because a lot of them had convinced themselves that Jupiter followed the second path to formation. Galileo's findings are awkward for theorists, to say the least.

The composition measurements also say something else is missing: complex organic molecules. This, project scientists think, is due to the relative scarcity of Jovian lightning, which provides energy to synthesize such molecules.

"We built a sophisticated transistor radio in hopes of detecting lighting, like you can pick up static on your car radio," says probe investigator Lou Lanzerotti of Bell Laboratories. "But we didn't know what to expect." Voyager had imaged flashes of lightning, and the probe's instrument was designed to pick up any bolts within about 10,000 km of the craft. The probe detected some 50,000 individual lightning bolts, but this is 3 to 10 times less than the rate found on Earth.

As the probe plummeted — it fell at about 100 miles an hour — its ride was anything but smooth. Unlike Earth's winds, driven by solar heating, Jupiter's weather comes from within. "Jupiter's winds appear to originate in the heat from the deep interior," says Young. He compared the ride to that of an airplane flying through a major storm. "You certainly wouldn't have wanted to be inside!"

Scientists expected that the winds would diminish as the probe sank deeper. Instead, by the time the probe fell silent, the winds had strengthened from 360 km/hour at the cloudtops to 540 km/hr at last measurement. By this point, 150 km below the altitude when the probe began its data-taking, it had reached a depth where the pressure was 22 bars and the outside temperature was 300° F. Bouncing on its shroud lines and buffetted by turbulent winds, the probe lost contact with the orbiter and its mission ended, 57 minutes after it began.

What happened then? No one knows how the probe met its end. But its fate can be guessed by the materials it was made from. The Dacron parachute probably melted about an hour after the last signals were sent. With the parachute gone, the probe fell quickly into the hot dark depths. Roughly 40 minutes later, at a temperature of 1,200° F and a pressure of 260 bars, the aluminum in the probe softened and turned liquid. Blobs of molten aluminum streamed off the plummeting probe like hot wax off a lit candle. Vaporizing, they became part of Jupiter.

Many more parts of the probe — pieces of planet Earth in an utterly alien environment — suffered the same fate. The last major item to go was the titanium hull. Titanium doesn't melt until 3,100° F, which comes at a depth of 2,000 bars. The end was quick. As the hull became molten, it broke into droplets. Then these too flashed into gas and vanished into Jupiter's roiling atmosphere.

The probe's mission is over. But for the orbiter, it's just beginning. Flight controllers spent February playing back the tape recorder, double and triple-checking that all the data have been sent correctly back to Earth.

In March, mission controllers fire the craft's engine to increase the distance at which the orbiter comes closest to Jupiter. (This is necessary because a second pass through the intense radiation belts near Io would probably destroy the spacecraft's electronics.) In April, the spacecraft gets a rest from housekeeping chores and can do some science. But later in April, new flight control software has to be loaded into the orbiter and checked out. That will take until about the middle of May.

Then the craft will be on course and ready for its first close-up satellite encounter, with Ganymede, on June 27, 1996. ☐

Robert Burnham is editor of ASTRONOMY.

Approaching the Edge of Space & Time

Hubble's latest image provides a view of the early universe, when the first galaxies were coming together.

by Robert Naeye

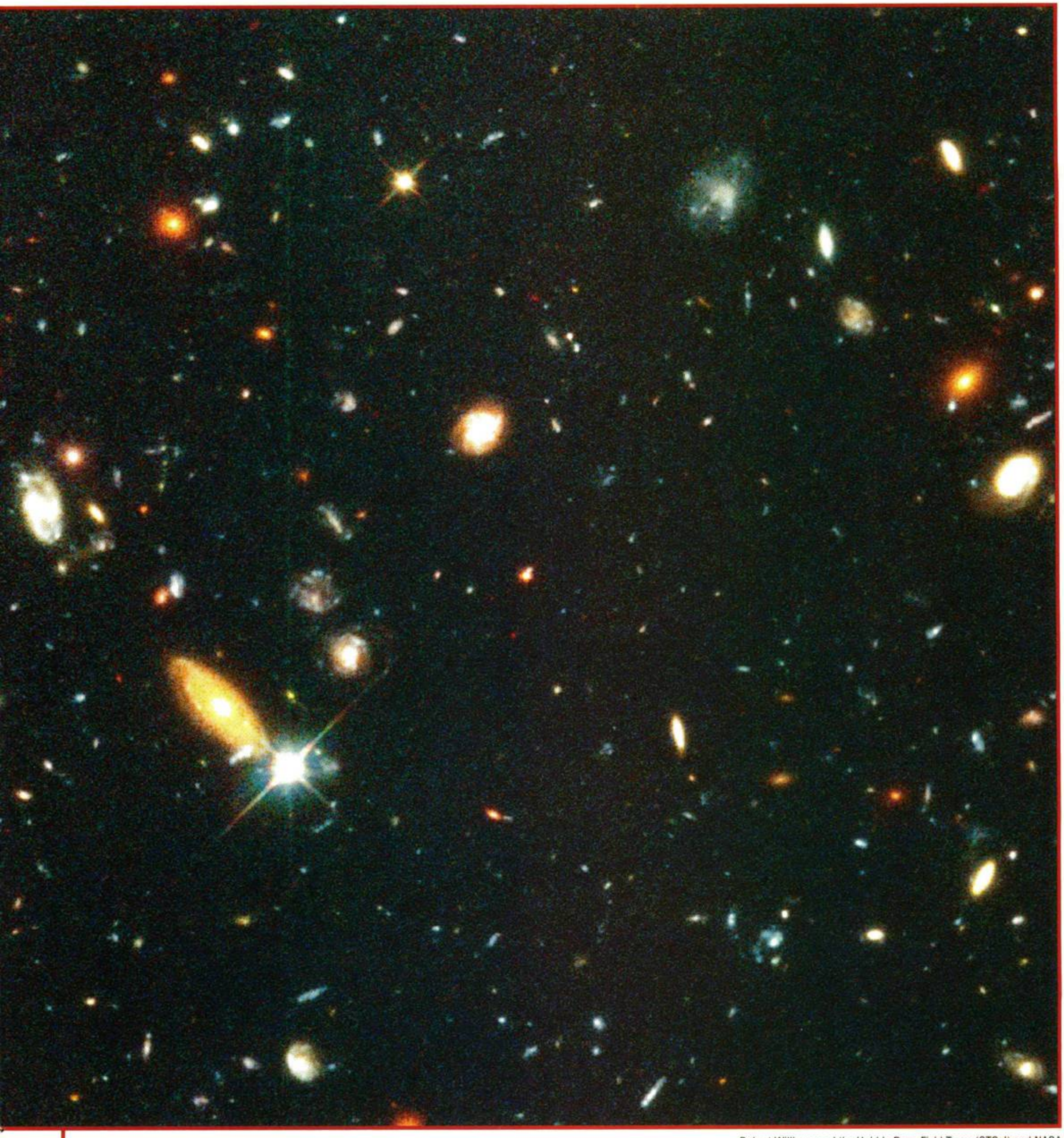
Every week or two it seems scientists release another breathtaking image from the Hubble Space Telescope. This latest Hubble photo is in many respects the most spectacular one yet. It provides a look deeper into space, and thus further back in time, then any photograph ever taken. It gives us a snapshot of the universe when it was less than 1 billion years old. We're looking across 10 to 20 billion light-years of space, and 10 to 20 billion years of time.

The image captures 1,500 to 2,000 galaxies at various stages of evolution. We see the faintest galaxies, unassuming red smudges, as they existed less than 1 billion years after the big bang. "The variety of galaxies we see in the early universe is amazing. There are large ones and small ones, red ones and blue ones, very structured ones and also very amorphous ones," says Robert Williams, director of the Space Telescope Science Institute in Baltimore, Maryland. "We are clearly seeing some of these galaxies as they were more than 10 billion years ago, in the process of formation. As the images have come up on our screens, we have not been able to keep from wondering if we might somehow be seeing our own origins in all of this. This has been an unbelievable experience."

The dimmest objects are nearly 30th magnitude, which is how bright the glow of a cigar would appear from the Moon. To capture objects this faint, Hubble had to stare at a tiny spot in space for 10 consecutive days, over 150 Earth orbits. These 10 straight days of observing time were broken into 342 exposures, lasting 15 to 40 minutes each. Separate images were taken in ultraviolet, blue, red, and infrared light and then combined into a single color picture. Astronomers can infer the galaxies' distances, ages, and compositions based on their color.

Hubble beamed this image to scientists this past December, so scientific analysis has just begun. Astronomers expect the photo to help answer questions about how soon after the big bang galaxies first appeared, and how galaxies evolved over the lifetime of the universe.

The image will answer questions about the universe's destiny as well as its past. By carefully measuring the sizes and brightnesses of the distant galaxies, and comparing them to nearby galaxies, astronomers will be able to determine how much spacetime is curved. This in turn will tell them whether the universe is destined to expand forever, or whether it will collapse back upon itself in a fiery death some unimaginable time in the future. ☐



Robert Williams and the Hubble Deep Field Team (STScI) and NASA

DEEEEEEP GALAXIES. The faintest smudges represent galaxies that formed less than 1 billion years after the big bang, eons before our solar system was born. This field covers a patch of sky the width of a dime 75 feet away.

A LOOK THROUGH TIME. In this enlarged detail, blue objects tend to be close, while the red objects tend to be farther away. The most distant galaxies will help astronomers unlock the secrets of galaxy formation.

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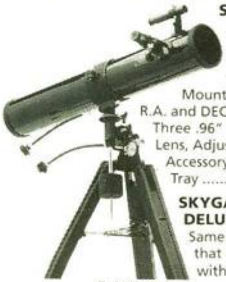

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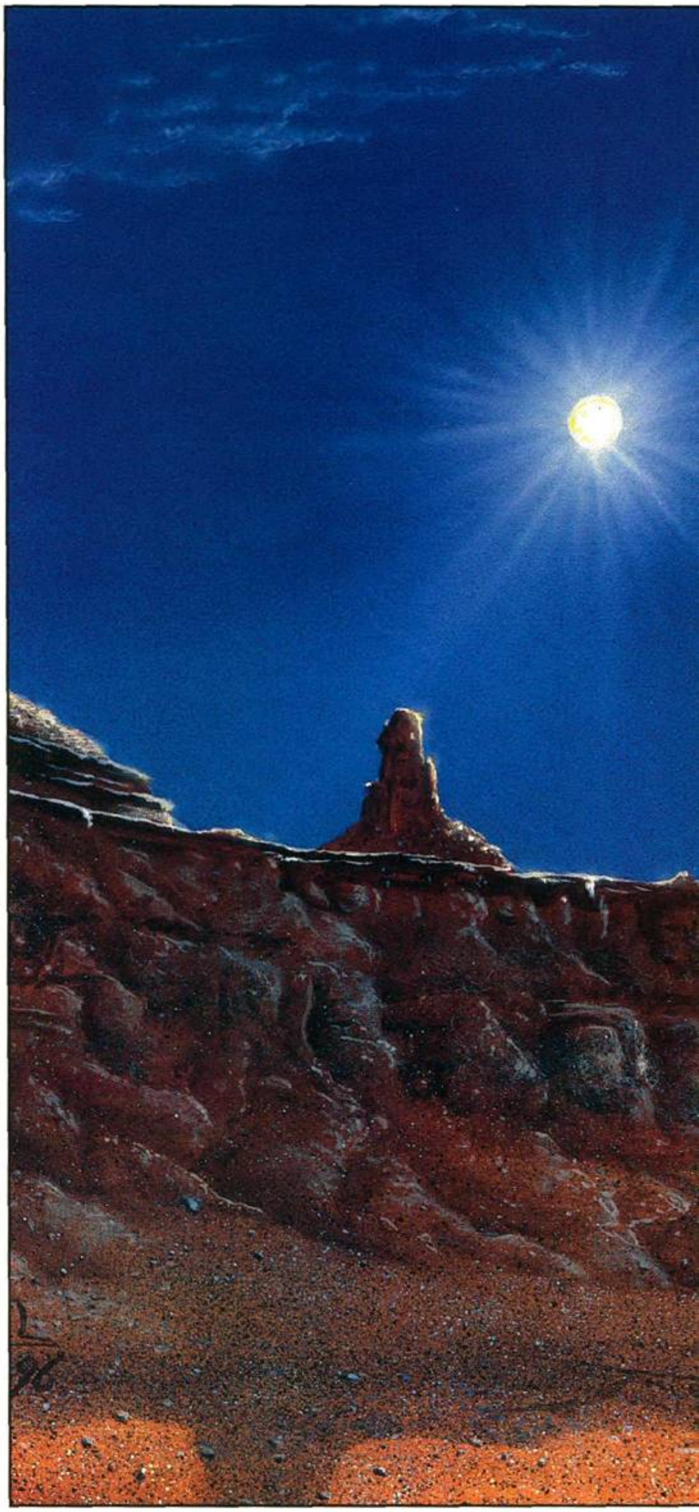
2 New Solar Systems

Astronomers have discovered two new planets orbiting Sun-like stars. More planets are soon to follow, improving the chances for finding extraterrestrial life.

by Robert Naeye



In 1801, the Italian astronomer Giuseppe Piazzi discovered a faint world orbiting the Sun beyond Mars. The object, later named Ceres, caused quite a sensation because it filled in a gap between Mars and Jupiter where astronomers had expected to find a planet. But to astronomers' chagrin, a new "planet" was discovered in the gap just one year later. Then another one followed in 1804, then another, and another. . . . By 1900, astronomers had found 463 of these objects, now called asteroids.

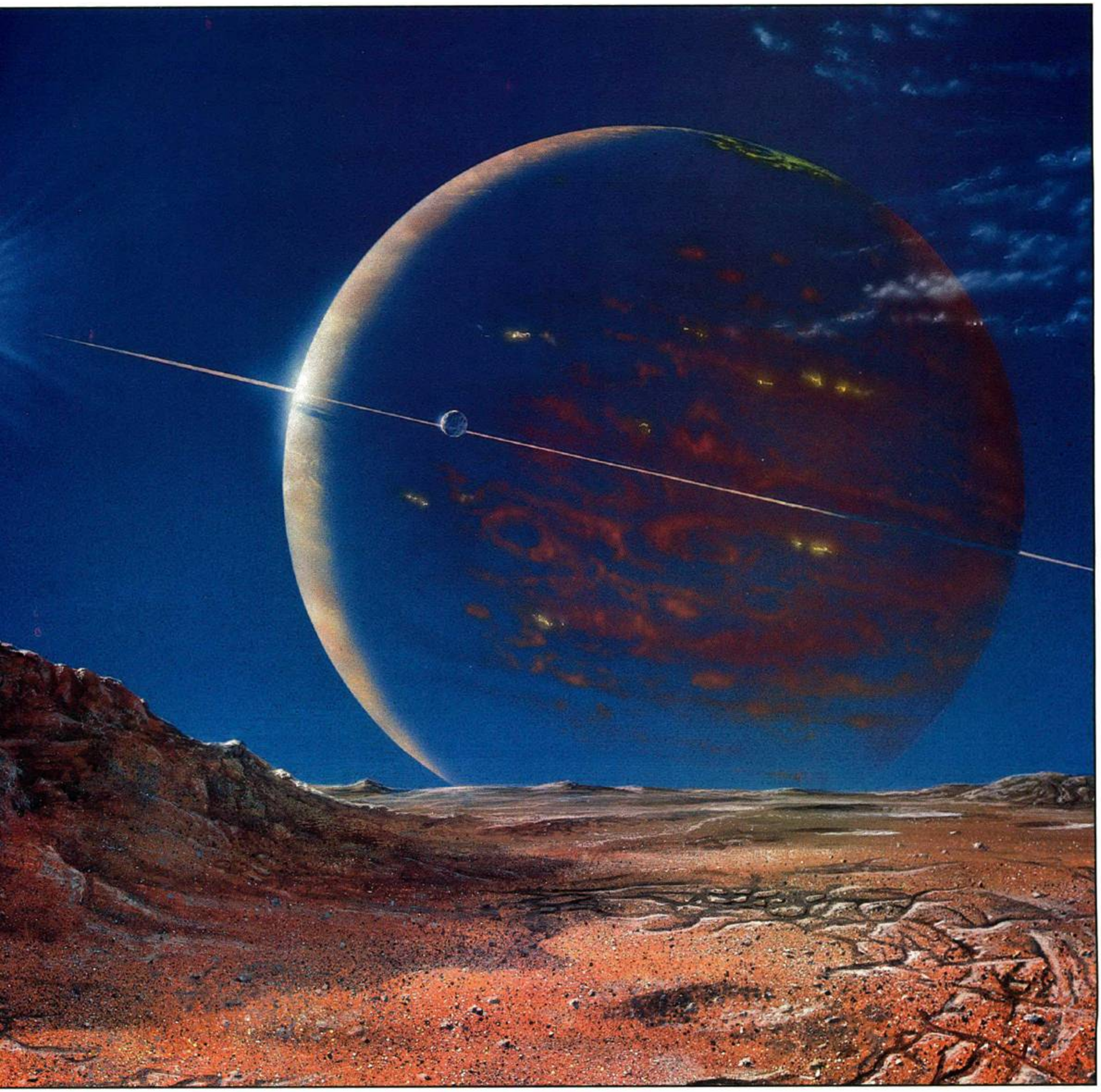
History has a way of repeating itself. Just as the discovery of the first asteroid opened the floodgates, the same thing is happening with the discovery of planets orbiting distant stars. In 1992, astronomers discovered the first planetary system beyond our own. Then in October 1995, Swiss astronomers Michel Mayor and Didier Queloz announced the second. And then, just three months later, Geoff Marcy of San Francisco State University and Paul Butler of the University of California at Berkeley chimed in with two more. As you read this, still more announcements are in the making. "I'm confident that many new planets will be discovered in the coming years," says Mayor.

Mayor's optimism stems from the fact that the technology of planet detection has crossed a threshold. Astronomers are arming themselves with a new generation of computers and optical instruments. Planets will start popping out of the woodwork, yielding a treasure trove of information about how common planets are, how planets form, and how prevalent life might be in the universe. "We are at a gateway to a new era in science," says Marcy, "an era in which we compare the nine planets in our solar system to their planetary cousins in other solar systems."

Meet the New Planets

The first two planetary systems discovered beyond our own are totally unlike our solar system and totally hostile to life. The first system involves three terrestrial-mass planets orbiting a pulsar, the collapsed remnant of an exploded star (see "Second Chance Planets," January 1996). The second star discovered to have at least one planet, 51 Pegasi, is a Sun-like star. But its planet is a Jupiter-mass world orbiting at only 1/100 the Jupiter-Sun distance, making astronomers wonder if it has any relationship to the planets in our solar system (see "Is This Planet for Real?" March 1996).

The two new planets discovered by Marcy and Butler are still pretty weird by solar system standards, but as Marcy says, "They bridge a gap between 51 Pegasi — and its close orbit — and the planets in our solar

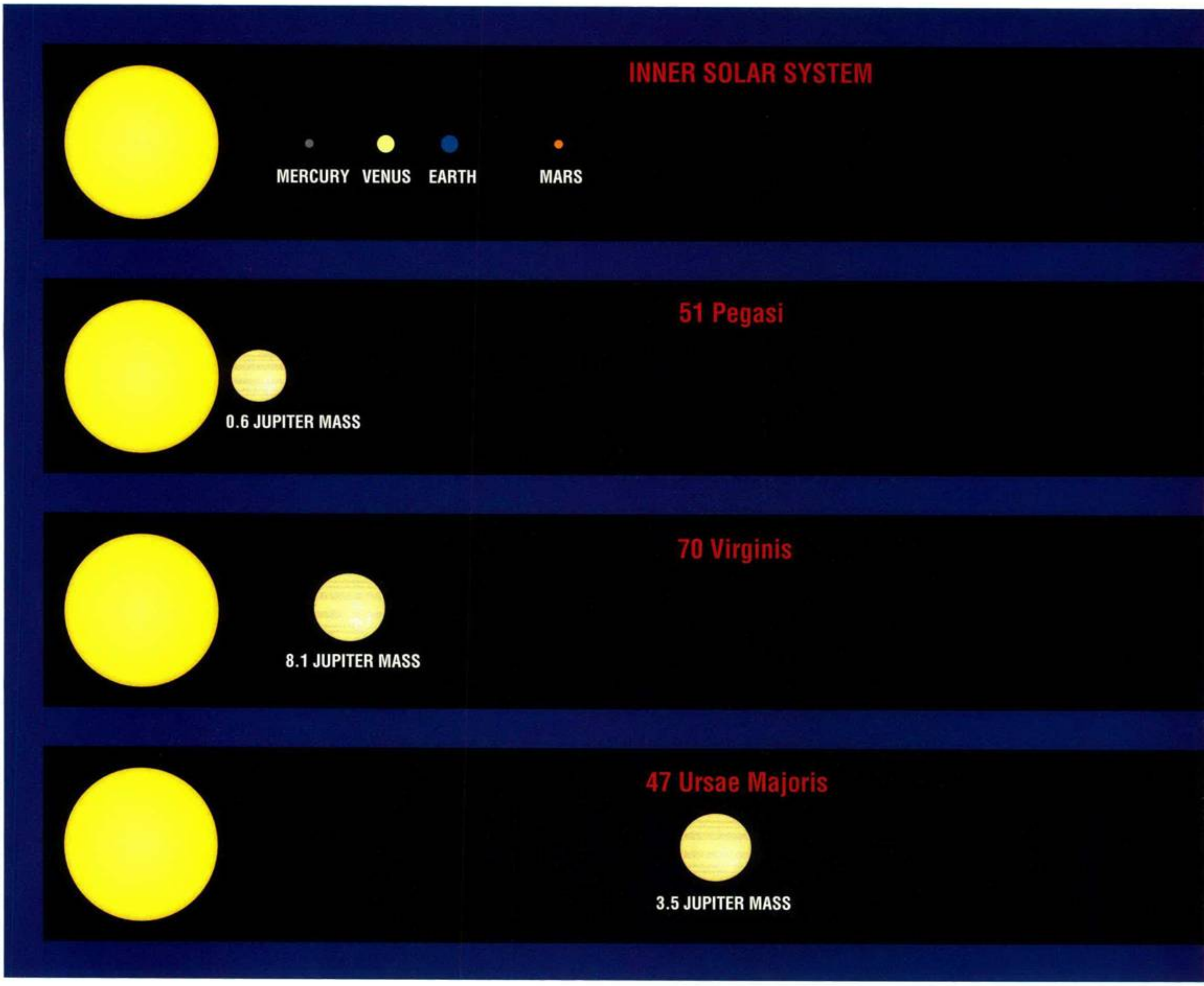


Michael Carroll

A BRAVE NEW WORLD orbits the solar-type star 70 Virginis. This planet contains roughly 8 times the mass of Jupiter. Temperatures on the planet or orbiting moons might be just right to support life.

system." Both planets are heavier than Jupiter, and they orbit much closer to their host stars than Jupiter orbits the Sun. But neither planet orbits as close as the 51 Pegasi planet (now known as 51 Pegasi B) orbits its star. Just like 51 Pegasi B, the new planets orbit stars that are similar to the Sun in terms of size, mass, and temperature. The stars, 47 Ursae Majoris and 70 Virginis, are solitary stars located roughly 40 to 70 light-years from Earth, close enough to be seen with the naked eye under a dark sky.

47 Ursae Majoris B weighs in with a mass of around 3.5 Jupiters. It is about twice as far from its host star as Earth is from the Sun. If it were in our solar system, it would orbit the Sun between Mars and Jupiter, just a little inside the realm of the asteroids. It takes the planet three Earth years to complete one orbit, tracing an almost perfect circle. Its distance from the parent star gives it a temperature of about –80° C (–112° F).



Diagrams, ASTRONOMY: THOMAS L. HUNT

FOUR SUN-LIKE STARS are known to have planets, but the systems differ significantly from one another.

70 Virginis B is considerably heavier. It tips the scale at a hefty eight Jupiters, making it the beefiest known planet to date. The planet orbits relatively close to its star, at an average distance only 4⁄10 Earth's distance from the Sun, which would put it just beyond the orbit of Mercury in our solar system. It races around 70 Virginis in an elliptical orbit every 117 days.

At the moment, astronomers know virtually nothing about the new planets other than their masses and orbits. Because of the planets' sheer bulk, astronomers presume they are giant gaseous planets like Jupiter, with rocky cores containing the mass of at least 10 or 20 Earths. But astronomers can't rule out the possibility that one or both planets could be made of rock, nickel, and iron.

Each new planet has one major thing going for it. 47 Ursae Majoris B is roughly Jupiter's mass in a Jupiter-like orbit. "It's the first planet that kind of looks like it would fit into our solar system," notes Butler. This planet is not exactly Jupiter's twin, but it's not a complete oddball either.

Astronomers are excited about 70 Virginis B because at its distance from the star, the temperature at the cloudtops should be around 85° C (185° F), which is the temperature of lukewarm coffee. Marcy and Butler have nicknamed the planet "Goldilocks" because the temperature in the atmosphere is "just right" for liquid water. In addition, organic molecules — the building blocks of life — could form. The planet is probably a lifeless ball of gas, however. If it is anything like Jupiter, it's a stormy, violent world with winds that top 300 miles per hour — not exactly a choice vacation spot (see "Into the Maelstrom," page 42).

Even if these new planets are unlikely abodes for life, it's conceivable they have moons with atmospheres that moderate the climate, making life possible. All of the giant planets in our solar system boast a

JUPITER

Comparison of Planets

	Earth	Jupiter	51 Pegasi B	70 Virginis B	47 Ursae Majoris B
Mass	0.003	1.00	0.6	8.1	3.5
Diameter	0.09	1.00	0.32 to 1.35	0.35 to 1.05	0.35 to 1.1
Distance from Star	1.00	5.20	0.05	0.43	2.1
Orbital Period	1 year	11.9 years	4.2 days	116.7 days	3.0 years
Day Temperature (°C)	15	–150	1000	85	–80
Tug on Star (meters per second)	0.1	12.5	53	311	45
Eccentricity	0.017	0.048	0.00	0.38	0.0

Comparison of Stars

	Sun	51 Pegasi	70 Virginis	47 Ursae Majoris
Diameter	1.0	1.4	1.9	1.1
Mass	1.0	0.95	0.9 to 1.0	1.0 to 1.1
Temperature (°C)	5500	5430	5200	5590
Luminosity	1.0	1.8	2.9	1.4
Metallicity	1.0	1.2 to 1.5	0.8	1.0
Spectral Type (main sequence)	G2	G3	G4	G0
Distance (light-years)	—	50 to 65	55 TO 70	40 TO 50

family of moons and a set of rings, so it's not farfetched to think that the new planets have moons and rings as well, although this remains pure speculation.

It's also possible that one or both systems have other planets, including Earth-sized planets in Earth-like orbits. Marcy's and Butler's search can't detect Earth-mass planets. Because our solar system has nine planets, 70 Virginis or 47 Ursae Majoris could have terrestrial planets lurking in the shadows.

Perhaps more importantly, the existence of planets around four Sun-like stars suggests that many other Sun-like stars have planets as well. "What's exciting is that these planets are residing in just the position that our own terrestrial planets — Venus, Earth, and Mars — reside, and it gives us tremendous hope that we will someday find Earth-like planets at these distances from other host stars," says Marcy.

How to Find Jupiter

Astronomers don't know much about the planets because they don't yet have the capability to take pictures of them. The planets are simply too dim and too close to their own suns to be seen directly. For example, 70 Virginis B is at most only 0.04 arcsecond from its star, which is equivalent to the width of a penny as seen from 60 miles. Even the Hubble Space Telescope can't resolve the planets in their stars' glare.

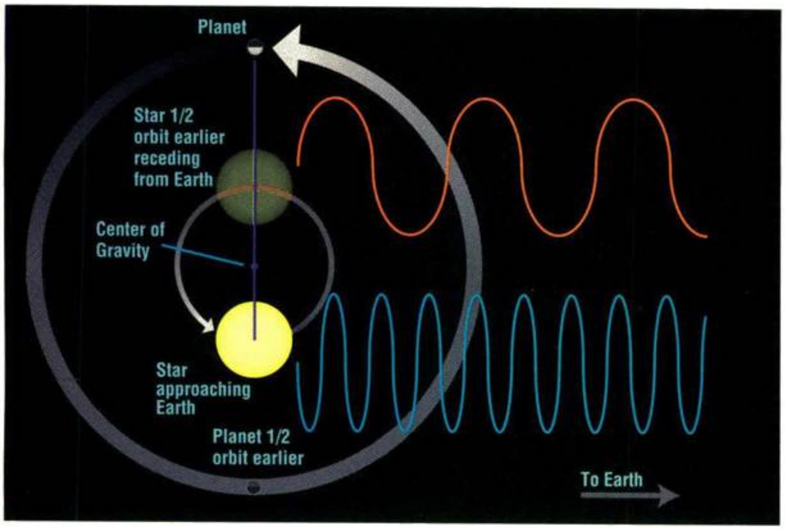
Marcy and Butler found the planets by using the exact same method that Mayor and Queloz used to discover 51 Pegasi B. As a planet goes around a star, it pulls on the star, causing it to trace a small circle. If the planet is massive enough, this motion produces a subtle yet detectable change in the star's spectrum, called a Doppler shift. When the star approaches Earth, it's spectrum shifts toward the blue. When the star moves away, the spectrum shifts toward the red.

When this Doppler shift is plotted on a chart, it shows up as a repeating wave. The height of the wave crest tells astronomers how strongly the planet tugs on the star, with a degree of uncertainty due to the unknown inclination of the planet's orbit. The period with which the pattern repeats itself is the length of time it takes the planet to orbit the star. From this, astronomers can employ Newton's laws to deduce the planet's distance from the star and hence its mass.

Marcy's and Butler's alien counterparts living on either new planet could discover Jupiter, and possibly Saturn, by using the same method. Jupiter causes the Sun to move at a speed of 12.5 meters per second (28 miles per hour). Fortunately for Marcy and Butler, they have an easier task. These new planets are both more massive than Jupiter and orbit closer to their host stars, and thus exert a stronger tug. 47 Ursae Majoris B causes its star to move at 45 meters per second (100 mph). And 70 Virginis B is so massive and so close to its star that it causes its host to wobble at a whopping 311 meters per second (700 mph). Because Marcy and Butler can detect motions as small as 3 meters per second (a brisk walk), 70 Virginis B stands out like a pro basketball player in a crowd of children. As Butler puts it, "We've built an enormous sledgehammer to crack a walnut."

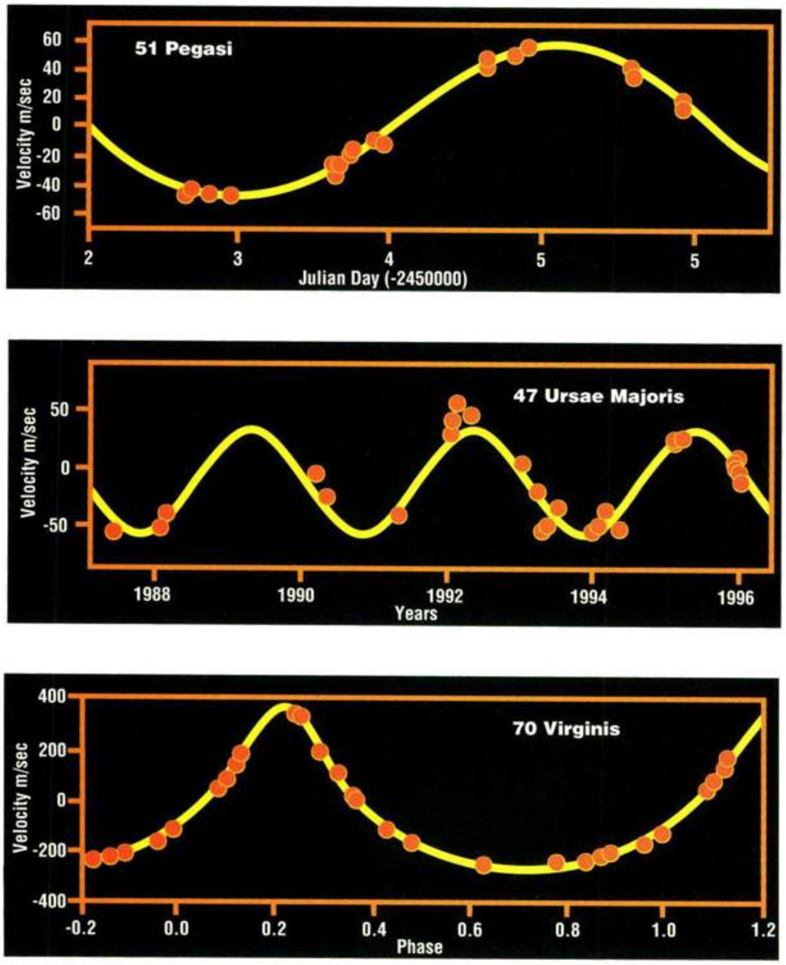
Picking the Plums

Marcy and Butler have been playing this game since 1987, using Lick Observatory's 3-meter telescope to observe 120 solar-type stars. Because a planet



THE TELLTALE TUG. A star and its companion orbit around a common center of gravity. The motion of the star produces changes in the star's spectrum, which show up as a blueshift of light when the star is approaching Earth, and a redshift when the star is receding.

THAT'S A PLANET! Astronomers plot the changing velocity of a star on a graph. The height of the wave crest indicates the planet's mass. The distorted shape of 70 Virginis' wave is a result of its planet's elliptical orbit.



search led by Canadian astronomers Bruce Campbell and Gordon Walker had failed to turn up planets more massive than Jupiter orbiting 21 solar-type stars, Marcy and Butler concluded that they needed to improve their precision in order to find less massive planets. Over the past eight years, while continuing to observe their 120 stars, they concentrated their efforts on steadily improving their instrumentation and software rather than analyzing their data.

But when Mayor and Queloz announced 51 Pegasi B in October 1995, Marcy and Butler suddenly realized that some planets might be easy pickings. Astronomers from the University of California at Berkeley allowed Marcy and Butler access to the powerful computers they needed to analyze their mountain of data. Marcy and Butler ran six computers day and night to analyze 60 stars. Just a few weeks before the January 1996 American Astronomical Society convention in San Antonio, Texas, the telltale wave signature of the two planets popped up on their screens. "We had two Eureka moments, which is more than we could imagine. It was stunning," recalls Marcy.

But if Marcy and Butler had analyzed their data sooner, they could have been the first to announce a planet orbiting a Sun-like star. "The 70 Virginis planet has sat on our hard disk for the last seven years," laments Marcy.

The Swiss group's precision of 13 meters per second isn't nearly as good as Marcy's and Butler's 3 meters per second, but they too can easily detect the 311-meter-per-second tug of 70 Virginis B. Because Mayor hasn't published his list of 142 stars, Marcy and Butler didn't know if he was also observing 70 Virginis. During the three weeks prior to their January announcement in San Antonio, the Californians sweated it out, hoping the Swiss wouldn't beat them to the punch a second time in what Marcy calls a friendly competition.

These two new planets, plus 51 Pegasi B (which exerts a 53-meter-per-second tug), were the first ones discovered around Sun-like stars because they were easy to find, just as the first asteroids to be found were the biggest and brightest ones. Marcy and Butler call it "picking the plums." At press time, the duo had analyzed data on only 60 of their 120 stars. Butler suspects that two or three of their other 60 stars will bear plums, as will stars being observed by the Swiss group and a University of Texas at Austin group headed by William Cochran. "I predict that within one year, more extrasolar planets will be known than there are planets in our solar system," says Butler. "And that only counts normal stars. Pulsar planets are a whole other class."

Weirdos and Super Planets

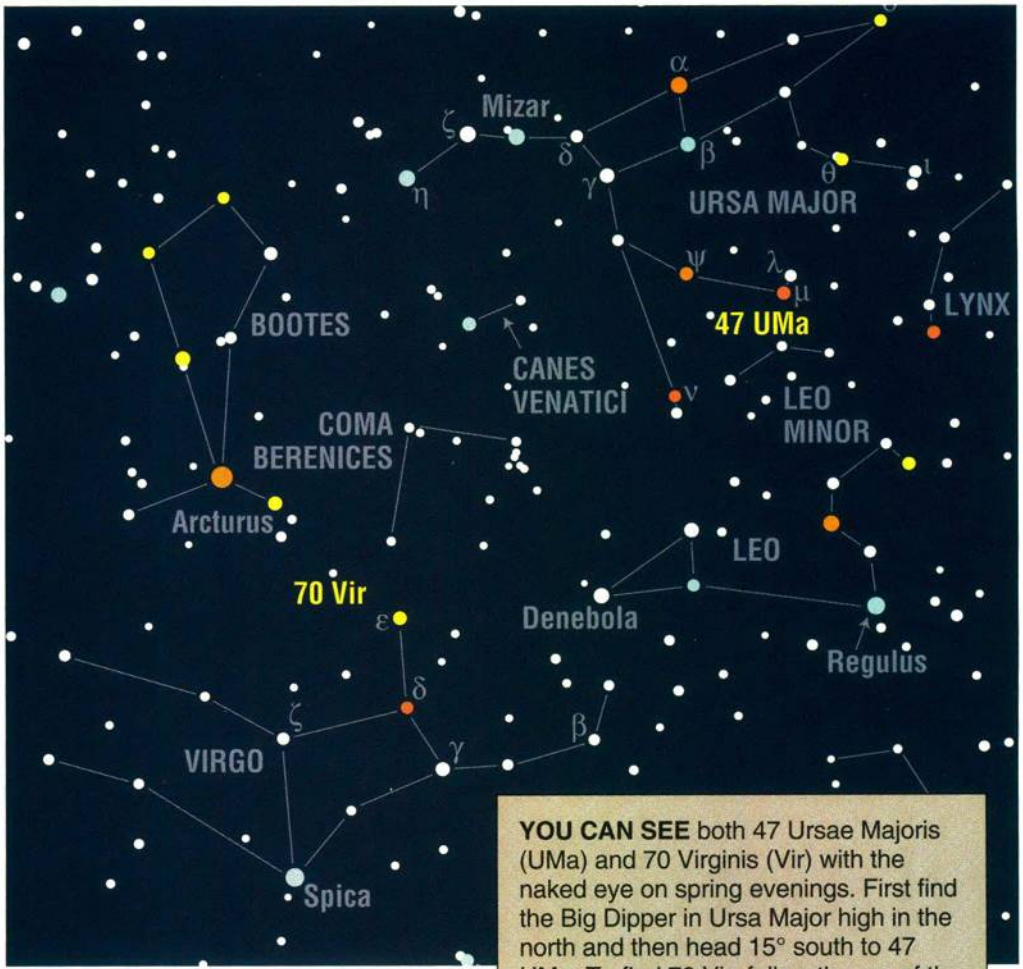
Once all the plums are picked, astronomers will next find Jupiter-mass planets orbiting farther from their stars. These planets are more difficult to detect not only because they tug more weakly on their hosts, but also because they take much longer to complete one orbit. Planet hunters like to see at least two orbits before they feel confident of a discovery. So a planet with Jupiter's 11.9-year orbit will take a decade or longer to detect.

Marcy's and Mayor's groups are seeing indications that some of their target stars are being orbited by planets in more distant orbits. Marcy and Butler expect to detect Jupiter-mass and Saturn-mass planets at Jupiter- and Saturn-like distances, but it will just take time. Even though their search can't detect the feeble 0.1-meter-per-second tug of Earth-mass planets, Butler notes that for every big planet they find, there are probably many smaller ones. "We're seeing the big guys, but this sort of implies that there are many, many more small guys, maybe guys like Earth."

One of the major questions raised by the new planets is whether planetary formation theories will have to be revised. Prior to these discoveries, theorists predicted that most planetary systems would be virtual carbon-copies of our own, with small rocky planets orbiting close in and massive gas giants farther out. But the existence of planets more massive than Jupiter orbiting in close proximity to three solar-type stars suggests that planetary systems are much more diverse than theorists had thought. "Our theory of planet formation is at best in an adolescent stage," says Marcy. "The theorists are just now beginning to recognize that they need to invoke much more physics that had not been anticipated. It's time to pull back and realize that we've been too cocky."

But theorists reply by noting that its unclear right now if these big, close-in planets are representative of planets in general, or whether they are weirdos that just happened to be easy to find. One theorist, Alan Boss of the Carnegie Institution, predicts, "I fully expect that we have just seen the tip of the iceberg. There must be a wealth of giant planets silently waiting out there at greater distances for their turn in the limelight." Boss adds that these massive inner planets — particularly 51 Pegasi B — might be indicating that giant planets sometimes migrate inward from their birthplace.

Another debate surrounds the nature of 70 Virginis B. Its large mass and eccentric orbit has fueled speculation that it might be a "failed star," known as a brown dwarf, rather than a planet. Marcy and Butler counter that it might represent the first example of a new type of object, a "super planet." They note that a similar object orbiting the dwarf star HD 114762 was discovered a decade ago by Harvard astronomer David Latham. Because astronomers didn't know quite what to make of this object, many assumed that it was just a low-mass star masquerading as a planet. But as Butler says, "In light of 70 Virginis B, people should probably rethink their position on HD 114762."



YOU CAN SEE both 47 Ursae Majoris (UMa) and 70 Virginis (Vir) with the naked eye on spring evenings. First find the Big Dipper in Ursa Major high in the north and then head 15° south to 47 UMa. To find 70 Vir, follow the arc of the Dipper's handle to brilliant Arcturus in Bootes; 70 lies about halfway between it and Epsilon (ε) Vir.

Over the next decade, these questions will be answered as planet-detection techniques continue to improve. It might even be possible to image planets in the near future, either with a new infrared camera to be installed on Hubble in 1997 or by using new optical instruments with ground-based telescopes. NASA administrator Daniel Goldin has hopped aboard the bandwagon. He recently called for a step-by-step program culminating 25 years hence in a 1-kilometer-long telescope array in space that could image oceans and continents on Earth-like planets orbiting nearby stars.

In the meantime, these recent findings give scientists and laypeople plenty to think about. "The great thing is that people of any age or nationality can look up and appreciate the profound value of these discoveries," says Marcy. "There aren't too many scientific discoveries you can point to that you know everybody can appreciate. Planets are something everybody knows about." □

Robert Naeye (rnaeye@astronomy.com) is an associate editor for ASTRONOMY. Last month he wrote about the planet orbiting 51 Pegasi.

SKY ALMANAC

Highlights
by Rick Shaffer

Date	Event
3	**First Views:** The Moon Rises In Eclipse . . . . . . (p. 61)
18	Asteroid Pallas Reaches Opposition . . . . . (p. 63)
21	The Lyrids Peak at New Moon . . . . . (p. 63)
23	The Moon Flags Tiny Mercury . . . (p. 56)
all month:	
	The Moon Flags Tiny Mercury . .(p. 56)
	Asteroid Pallas Reaches Opposition . . . .(p. 63)
	Observer's Challenge: Hunt Down a Quasar . . . . . .(p. 64)
	Hale-Bopp Rounds a Corner . . . . . .(p. 65)
	The Starry Sky: Coma Berenices(p. 62)

April features a sunset lunar eclipse for skywatchers in North America, while people the world over see inner planets Venus and Mercury shining at their best in the west.

by Deborah Byrd

During the waning daylight hours of April 3 in North America, the Full Moon slips into Earth's shadow and undergoes a total eclipse. Although the entire eclipse is visible from Europe and Africa, only North Americans living east of the Mississippi will see the tail end of totality and all of the partial phases that follow. For those observers, the Moon rises in eclipse.

The darkest part of our planet's shadow — the umbra — first nicks the Moon's face at 5:21 p.m. EST. Totality arrives at 6:26 p.m. EST when the Moon passes through the deepest part of our planet's shadow. At that time, the Moon rises just as the Sun sets for eastern North America. That evening moonrise for New York occurs at 6:17 p.m.; for Washington D.C., 6:28 p.m.; and for Miami, 6:34 p.m. EST. If you live near one of these places, the Moon that comes over the eastern horizon will be completely submerged in the umbra.

When the Moon dips into Earth's shadow like this, oftentimes it doesn't appear completely dark. Instead, it takes on a reddish cast due to light that filters through our atmosphere into the shadow. This dark red light will be tough to see during April's eclipse from North America because the Moon is so low in the sky, where the air is thicker and squelches the eclipse's subtle hues. That, combined with the effects of lingering twilight, will make spotting the eclipsed moonrise very challenging.

But another circumstance will make this eclipse all the more interesting for North American observers. With most eclipses, many observers tend to watch the partial phases leading up to

The Moon Flags Tiny Mercury

Aside from the faint outer planets, Mercury is often the toughest planet to spot. This is because the solar system's innermost planet seldom appears far from the Sun's glare in our sky.

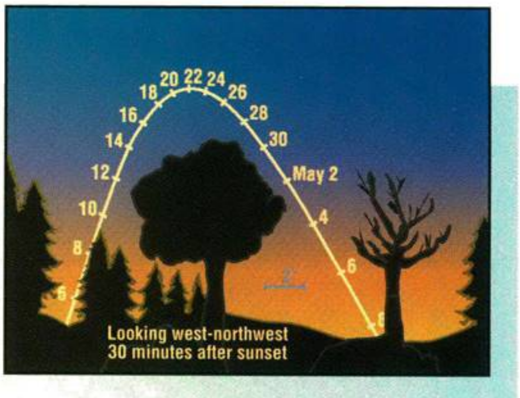
But this month, circumstances conspire to make Mercury an easy target for people observing from the midnorthern latitudes. At these latitudes on April evenings, the ecliptic makes a very steep angle to the western horizon. This steepness translates Mercury's meager angular separation from the Sun into an altitude above the western horizon after sunset. The net result is that April provides the best evening apparition of Mercury for 1996.

Although Mercury remains an evening object during April and the first two weeks of May, its best visibility falls between April 10 and May 5. On April 23, the night of greatest elongation from the Sun, Mercury appears as a 0.2-magnitude "star" 13° above the horizon 30 minutes after sunset and sets nearly two hours after the Sun.

One of this apparition's highlights occurs on the evening of April 19. The scene opens 20 minutes after sunset with the two-day-old Moon hanging low in the western sky. Soon thereafter, Mercury emerges from twilight about 8° to the right and just below the Moon.

Rounding out the view about half an hour later are two of winter's naked-eye star clusters: the dipper like Pleiades 10° above Mercury and the V-shaped Hyades, above and to the left of the Moon.

Use a telescope to compare the Moon's crescent phase with that of Mercury's half-lit appearance. The planet's phase shrinks over the coming two weeks. — *Rick Shaffer*



John Shibley

APRIL

3 Full Moon is at 7:07 p.m. EST; total lunar eclipse (page 61)

9 Asteroid Harmonia is at opposition

10 The Moon passes 5° north of Jupiter, 1 p.m. EDT
Last Quarter Moon is at 7:36 p.m. EDT
The Moon is at perigee (229,851 miles from Earth), 10:49 p.m. EDT

11 The Moon passes 5° north of Neptune, 8 a.m. EDT
The Moon passes 6° north of Uranus, 8 p.m. EDT

15 Venus passes 10° north of Aldebaran, 6 p.m. EDT
The Moon passes 4° north of Saturn, 9 p.m. EDT

17 New Moon is at 6:49 p.m. EDT; partial solar eclipse

18 Asteroid Pallas is at opposition (page 63)

19 The Moon passes 5° south of Mercury, 6 a.m. EDT

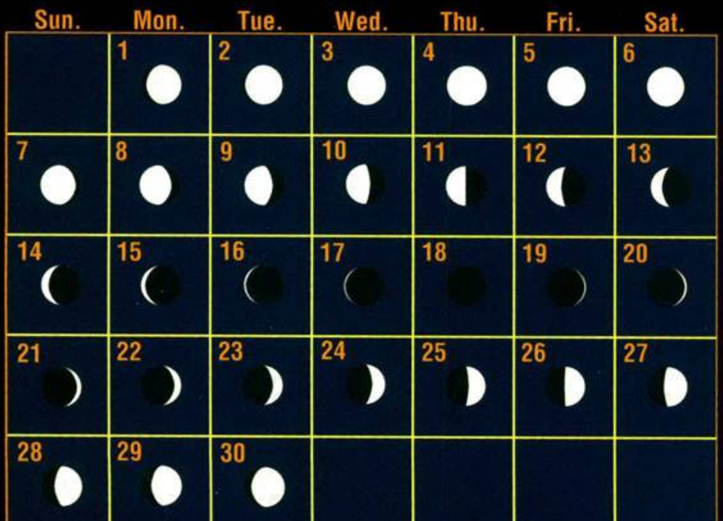
21 The Moon passes 9° south of Venus, 10 a.m. EDT
Lyrid meteor shower peaks (page 63)

23 Mercury is at greatest eastern elongation (20°), 4 a.m. EDT (page 56)

24 The Moon is at apogee (251,266 miles from Earth), 6:25 p.m. EDT

25 First Quarter Moon is at 4:40 p.m. EDT

26 Asteroid Flora is at opposition


Sun.
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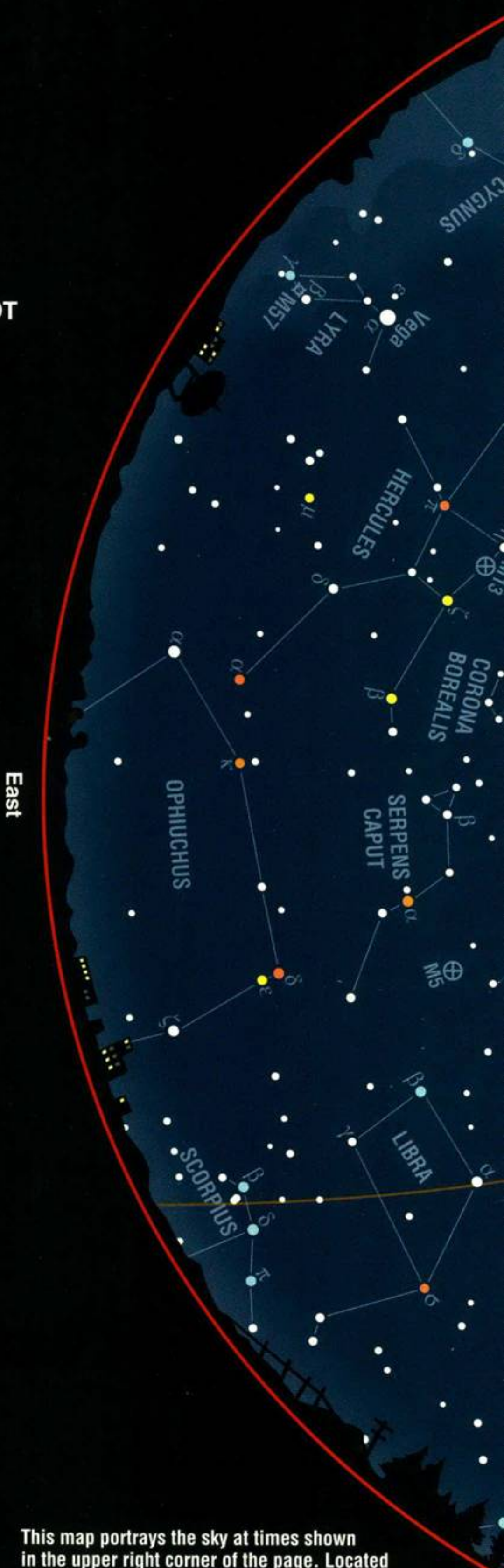
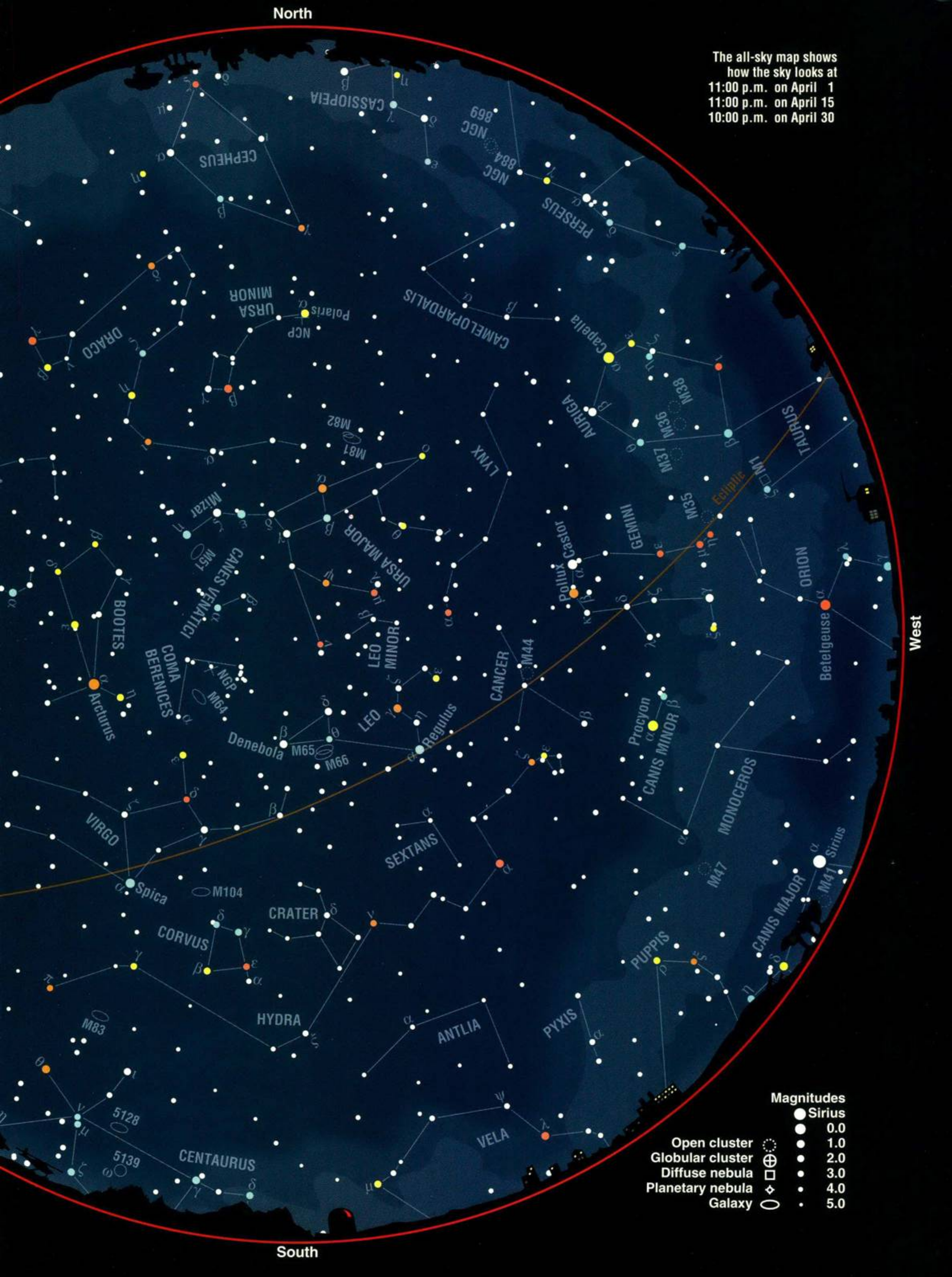
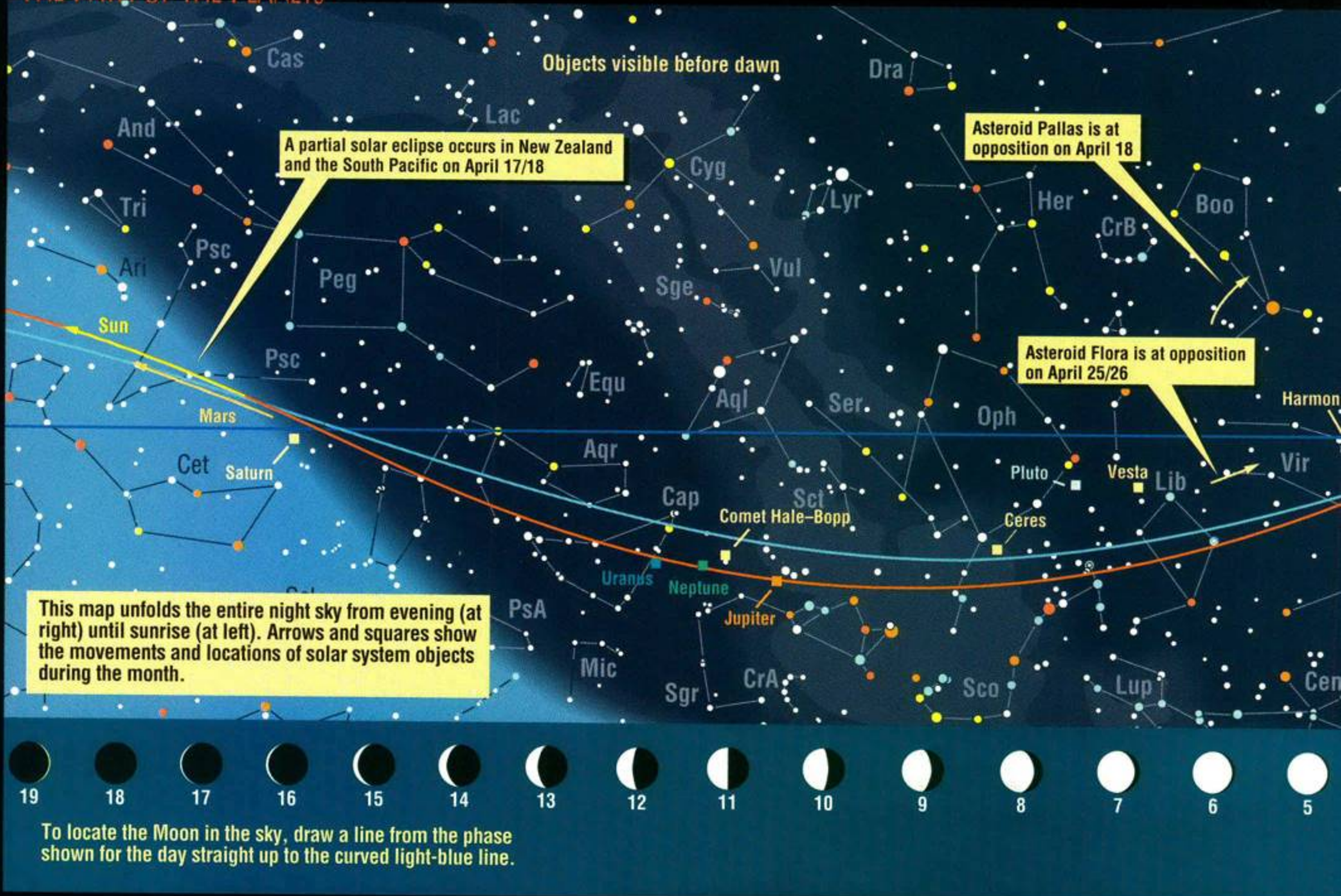

CYGNUS
M57
LYRA
Vega
HERCULES
M13
CORONA BOREALIS
OPHIUCHUS
SERPENS CAPUT
M5
LIBRA
SCORPIUS
East

This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


North
West
South
CASSIOPEIA
CEPHEUS
NGC 869
NGC 884
PERSEUS
URSA MINOR
Polaris
NCP
DRACO
CAMELOPARDALIS
Capella
AURIGA
M38
M36
M37
TAURUS
M1
Ecliptic
M35
M82
M81
LYNX
Mizar
URSA MAJOR
M51
CANES VENATICI
GEMINI
Castor
Pollux
ORION
Betelgeuse
BOOTES
COMA BERENICES
NGP
M64
Arcturus
LEO MINOR
CANCER
M44
Procyon
CANIS MINOR
LEO
Regulus
Denebola
M65
M66
MONOCEROS
VIRGO
SEXTANS
Spica
M104
CRATER
M47
Sirius
M41
CANIS MAJOR
CORVUS
PUPPIS
HYDRA
ANTLIA
PYXIS
M83
5128
5139
CENTAURUS
VELA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
11:00 p.m. on April 1
11:00 p.m. on April 15
10:00 p.m. on April 30

THE PATH OF THE PLANETS


Objects visible before dawn
Cas
Lac
And
Tri
Psc
Ari
Peg
Cyg
Lyr
Sge
Vul
Dra
Her
CrB
Boo
Sun
Psc
Equ
Aql
Ser
Oph
Mars
Cet
Saturn
Aqr
Cap
Sct
Comet Hale–Bopp
Uranus
Neptune
Jupiter
Pluto
Vesta
Lib
Ceres
Vir
Harmon
PsA
Mic
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CrA
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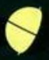
A partial solar eclipse occurs in New Zealand and the South Pacific on April 17/18

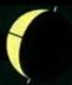
Asteroid Pallas is at opposition on April 18

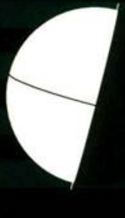
Asteroid Flora is at opposition on April 25/26

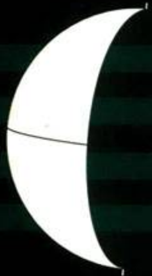
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.





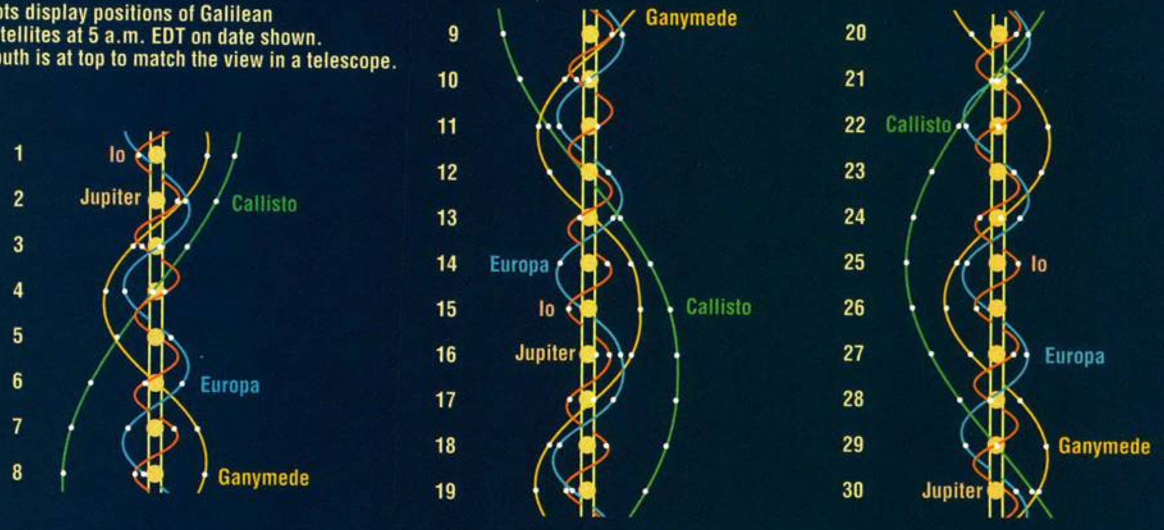


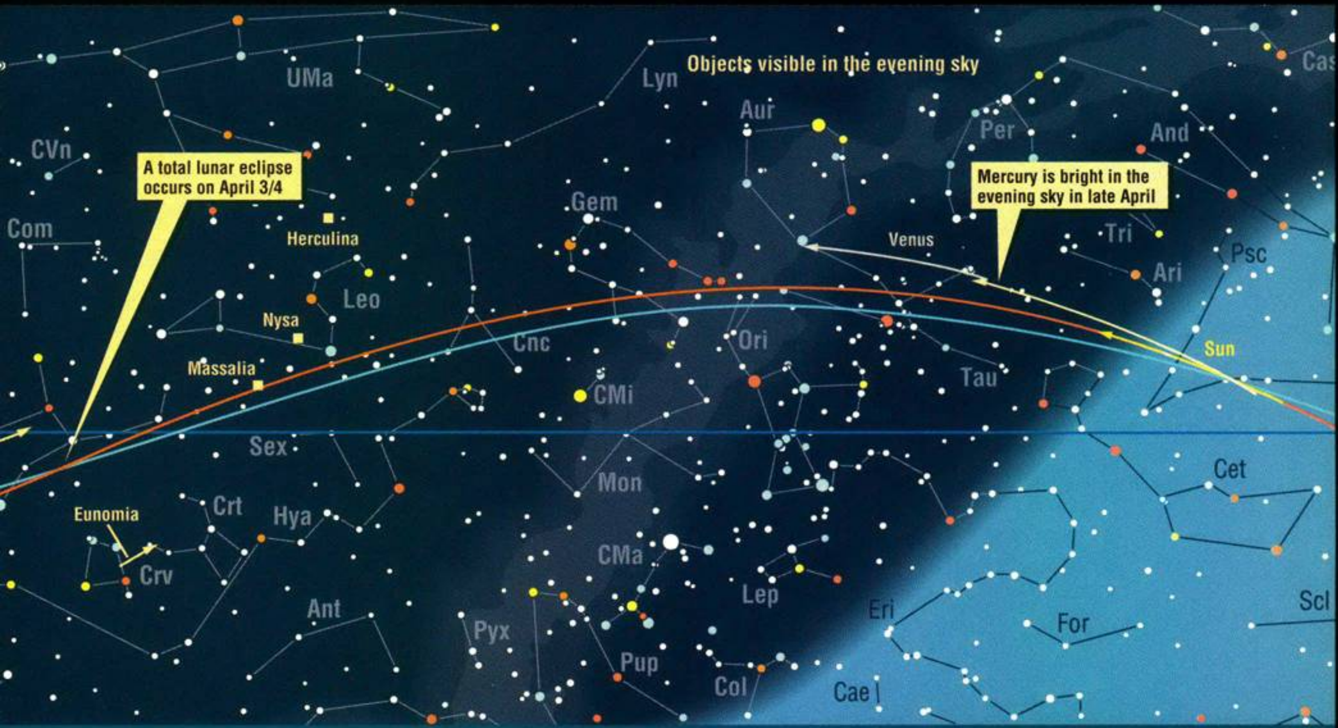


PLANETS	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	April 15	April 30	April 1	April 30	April 15
Magnitude	–0.8	1.4	–4.4	–4.5	1.2
Angular Size	6.3"	9.4"	23.5"	34.3"	3.9"
Illumination	67%	20%	51%	32%	100%
Distance (AU) from Earth	1.065	0.716	0.710	0.487	2.385
Distance (AU) from Sun	0.318	0.396	0.719	0.721	1.402
Right Ascension (2000.0)	2h38.2m	3h40.4m	3h37.7m	5h21.8m	1h02.1m
Declination (2000.0)	17°25'	22°16'	22°44'	27°39'	5°53'

JUPITER'S MOONS

Dots display positions of Galilean satellites at 5 a.m. EDT on date shown. South is at top to match the view in a telescope.




Cas
UMa
Lyn
Aur
Per
And
CVn
Com
Herculina
Gem
Venus
Tri
Ari
Psc
Leo
Nysa
Massalia
Cnc
Ori
CMi
Tau
Sun
Sex
Mon
Cet
Eunomia
Crt
Hya
Crv
CMa
Lep
Ant
Pyx
Pup
Col
Eri
For
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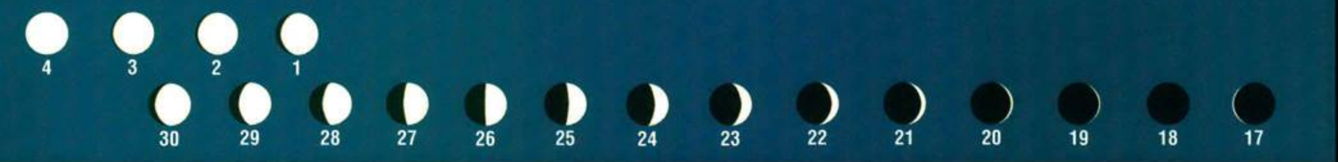
Cae

Objects visible in the evening sky

A total lunar eclipse occurs on April 3/4

Mercury is bright in the evening sky in late April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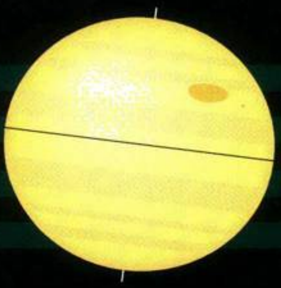
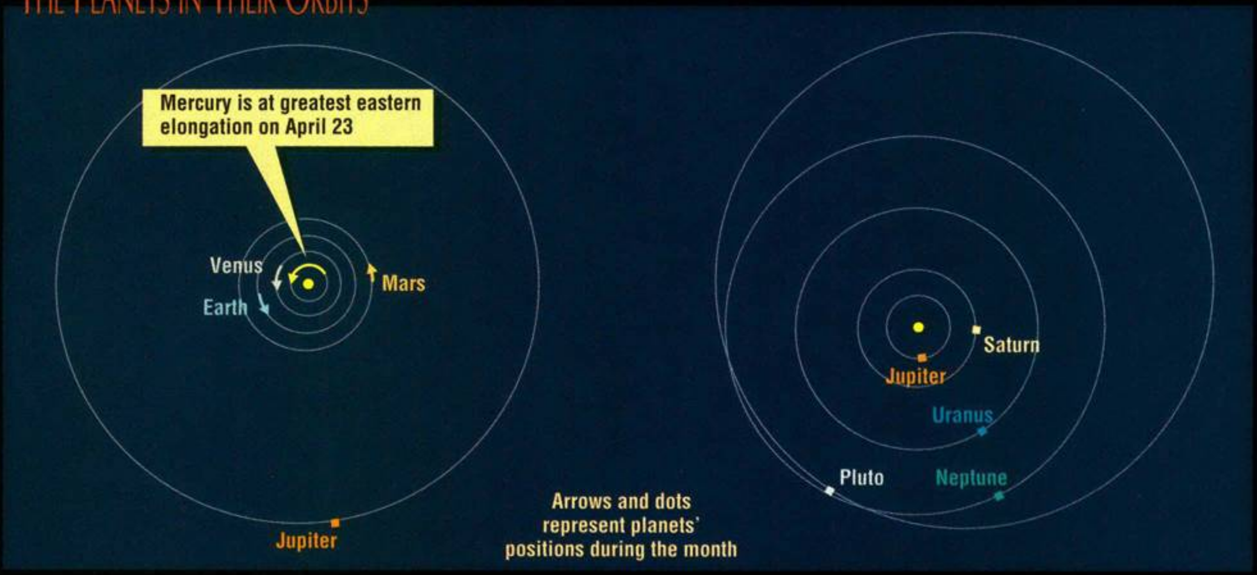


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
April 15	April 15	April 15	April 15	April 15
–2.3	1.1	5.8	7.9	13.7
39.5"	15.9"	3.5"	2.3"	0.1"
99%	100%	100%	100%	100%
4.993	10.451	19.894	30.188	29.113
5.232	9.547	19.761	30.163	29.896
19h14.1m	0h06.8m	20h27.5m	19h58.9m	16h13.1m
–22°15'	–1°30'	–19°43'	–20°08'	–7°32'

THE PLANETS IN THEIR ORBITS


Venus
Earth
Mars
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

Mercury is at greatest eastern elongation on April 23

Arrows and dots represent planets' positions during the month totality with deep fascination and growing excitement, only to ignore the latter stages completely.

This time, however, because North Americans miss everything preceding totality, they will probably spend more time watching the eclipse wind down. During these neglected stages, our planet's dark shadow slowly recedes from the Moon's face before finally disappearing into the blackness of space. That happens at 8:59 p.m. EST on April 3. The Moon leaves the last traces of Earth's lighter, penumbral shadow at 10:04 p.m. EST on April 3.

The farther west you live in North America, the less eclipse there will be to see. For example, the Moon rises at 6:23 p.m. CST as seen from St. Louis, about half an hour before totality ends. By the time moonrise occurs for Los Angeles at 6:17 p.m. PST, the dark umbral shadow has left the Moon's face and only the lighter penumbral shadow lingers. This sight will be obscured by haze close to the horizon.

But such less-than-perfect eclipse viewing conditions provide a golden opportunity of sorts — a chance to literally be a part of the eclipse.

Because the Moon and Sun lie in a line with Earth on the evening of April 3, sunset and moonrise occur within minutes of each other. This is a wonderful chance to see both events happen simultaneously, provided you view from a vantage point free of horizon clutter.

At the moment of sunset/moonrise, you will be standing in line with the Sun and the Moon. If the eclipse is still underway, the Earth beneath you will be casting its shadow on the Moon.

Beyond that, the eclipse shadow's ruddy cast is the light of your sunset combined with that of countless other sunrises and sunsets cascading upon the Moon's surface. Photons from the Sun are flying past you on their way to an eclipsed Moon, barely 1.2

First Views:
The Moon Rises in Eclipse

The Moon passes through Earth's shadow on the evening of April 3, offering up what's called a lunar eclipse. Europe, most of Africa, and the eastern half of South America witness the entire eclipse.

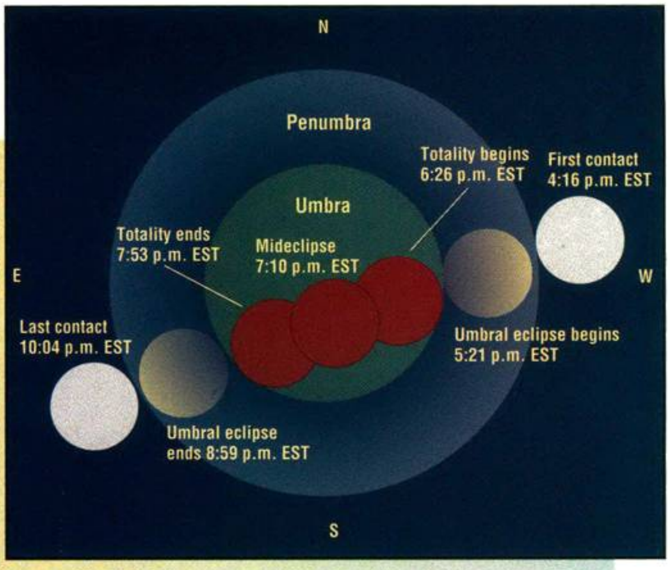
Observers on the east coast of North America see the Moon rise already fully eclipsed, deep in the Earth's umbral shadow. Those west of the Mississippi River will have to settle for second-hand accounts; the total eclipse ends before or right around moonrise.

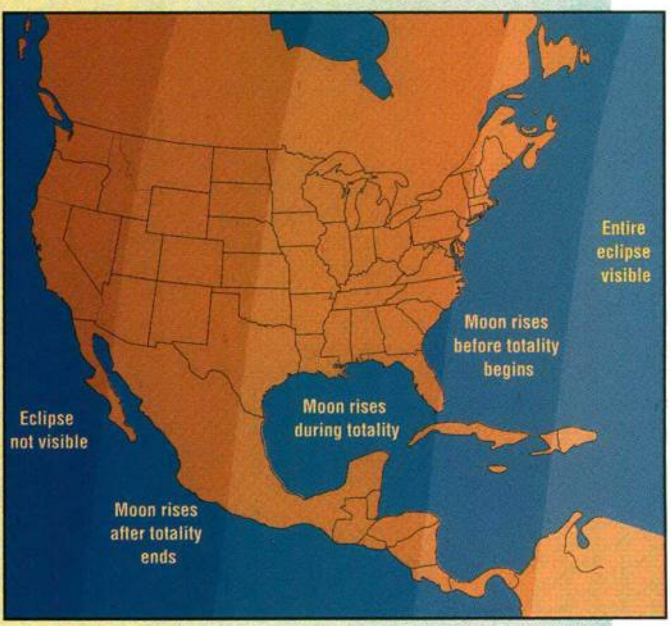
Because an eclipsed Moon looks fairly dim, finding it just above the horizon during evening twilight will be a challenge. To figure out where it will rise, go out to your site the night before and note where the almost-full Moon comes up. The darkened Moon will rise close to the same spot on eclipse night.

During the eclipse, note that some areas of our planet's shadow look darker and redder than others. This results from weather along Earth's sunrise and sunset line, an area through which the Sun's light passes on its way to the Moon. If a portion of atmosphere along this line has more cloud cover, the corresponding part of the Moon's disk is darker than other parts.

Even during mideclipse, the Moon appears lit in an aura of red light. This is because our atmosphere refracts, or bends, sunlight into Earth's shadow. We see the Moon bathed in red thanks to molecules of air and particles of dust that scatter more blue light than red light, which travels relatively unimpeded through Earth's atmosphere to the Moon.

One more aspect to ponder is our shadow's circular shape. How else, reasoned the ancient Greeks, could the shadow take a circular bite out of the Moon unless the Earth were round? — *R. S.*





Kirk Wines

light-seconds away.

As the nighttime grows darker and the Moon finally escapes the pall of Earth's shadow until next September's lunar eclipse, the planet **Venus** pops into view in the west as a dazzlingly bright "star."

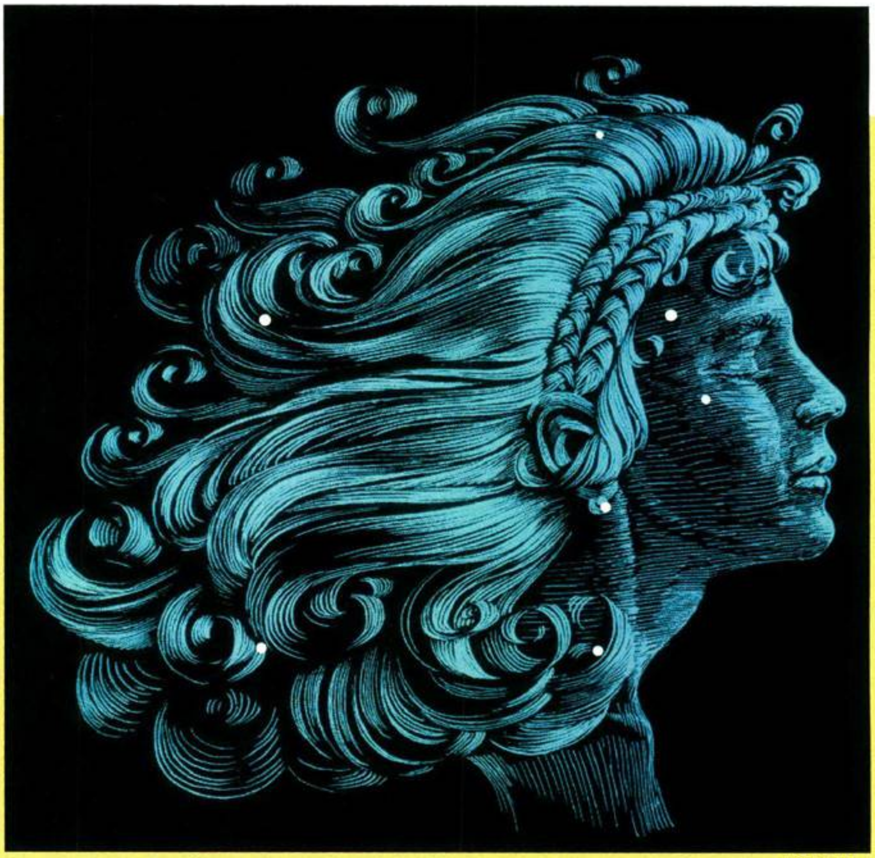
Greatest elongation, when it lies farthest from the Sun in the evening sky, comes on the night of March 31/April 1. On that evening Venus is 46° from the Sun and shines at magnitude –4.4. A telescope reveals the planet has a 'half moon' phase that will gradually take on the form of a fat crescent as April progresses.

The coming month sees many interesting sky objects near Venus in the evening sky. On the night of April 15, Venus lies just 10° above and to the right of the bright star Aldebaran in Taurus. Barely a week later, on April 20, Aldebaran is right next to the slim crescent Moon. Luna's waxing crescent edges closer to Venus the following evening.

Not too far away, **Mercury** also has an excellent apparition in the evening sky this month. The ecliptic, or path of the Sun, Moon, and planets, makes a steep angle to the western horizon on northern spring evenings. Thus, the best evening apparitions of Mercury always happen during the springtime, and 1996 is no exception.

Look for Mercury below Venus and Aldebaran toward the end of the first week of April. You'll be surprised at its brightness. By midmonth, it lies low in the west glittering like a jewel in the twilight sky at magnitude –0.8. A nearby young

The Starry Sky:
Coma Berenices



Keith Ward

A delicately beautiful constellation lies close to the zenith as twilight fades on these April evenings. It is so faint that you will need a dark country sky to enjoy it. Yet this conspicuous star pattern has been known throughout the history of astronomy. The ancient Egyptians called it Many Stars. Today we call this constellation Coma Berenices, otherwise known as Berenice's Hair.

To the naked eye Coma Berenices is a scattering of perhaps a dozen faint stars appearing so diffuse that, unless your sky is excellent, you might need some help in locating it. Look for it along a line between Denebola, the "tail" of Leo the Lion, and the end of the handle of the Big Dipper. Binoculars reveal many more stars and a small telescope even more.

The bright stars in Coma Berenices aren't just a chance alignment of stars along our line of sight. They form an actual star cluster whose members were born from a common cloud of gas and dust. Our Sun emerged from such a cloud, as did most stars in our Milky Way Galaxy. In Coma Berenices' case, the stars have yet to wander far from the stellar nest, and form what is called an open cluster of stars. Since this cluster is so close to Earth, only 250 light-years away, it covers more than 5° of our night sky. Most other, more distant open clusters are only visible in binoculars or a telescope.

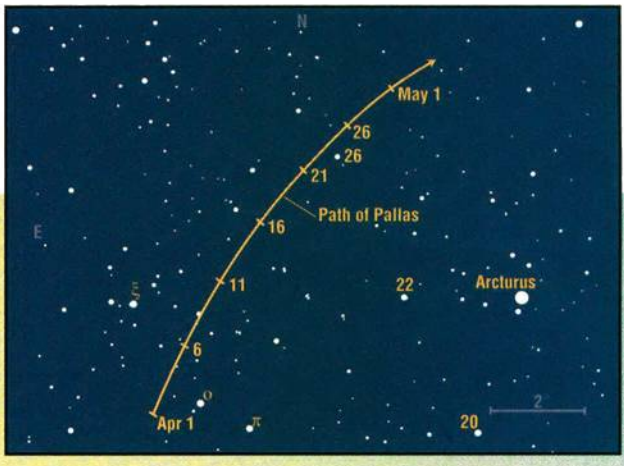
The folklore we have today about Coma Berenices comes from ancient Egypt. Legend holds that Queen Berenice was grief-stricken when her husband went off to war with the Assyrians. She vowed to sacrifice her long hair to the goddess of beauty if her king returned safely. The king did return, and Berenice was true to her promise. She cut off her hair and placed it in a temple, under the watchful eye of temple guardians.

One moonless night, when the world was dark, the king was struck with a longing to see his wife's beautiful hair again. He went to the temple and was met by the temple guardians. They told him that the hair had disappeared only moments before. Before the king had a chance to become angry, the guardians — thinking fast on their feet — informed him that the gods, so pleased by the sacrifice of Queen Berenice, had placed the queen's hair in the heavens for all eternity. Then the guardians pointed up to the sky, toward a beautiful scattering of faint stars. The king was satisfied that he could now see Berenice's hair whenever he wished.

No early stargazer could have enjoyed this region of the heavens more than we do today. Coma Berenices and its neighboring constellation Virgo are strewn with thousands of faint galaxies, part of a greater complex of galaxies astronomers call the Coma-Virgo galaxy cluster.

Turn your telescope in this direction one dark night and you might see several galaxies in a single field of view. Although today we know that space is occupied by galaxies in all directions from Earth, the Coma/ Virgo galaxies have not lost their allure. Because of this, the region holds the title of Realm of Galaxies. — *Deborah Byrd*

Asteroid Pallas Reaches Opposition



Asteroid 2 Pallas, the second minor planet discovered and the solar system's second largest, reaches opposition on April 18 among the background stars of Bootes. Opposition time offers you the best opportunity to see this world first glimpsed in 1802. For most of the month it shines at magnitude 8.2, dipping to magnitude 8.4 by month's end.

Radar studies of 380-mile-wide Pallas done during past oppositions (when Pallas was closest to Earth) show it to be approximately spherical in shape.

Since the disk of Pallas is far too small to resolve, observing this asteroid mostly involves just finding it. To do that, use the accompanying finder chart that includes the region just east of Arcturus. Once you've identified Pallas among its neighboring stars, revisit the area a couple of nights later to note the asteroid's movement. Pallas moves about ½° a day in a northwesterly direction. Rely upon quick sketches at the eyepiece rather than your memory to recall where it's been.

If you own a scope that tracks with the sky and a camera with at least a 200mm lens, try capturing Pallas' motion over several nights. Shoot 10-minute exposures on ISO 400 film with the lens set to its lowest f/number. ASTRONOMY welcomes all observations, both visual and photographic. — *R. S.*

COORDINATES FOR PALLAS*

Date	R.A.	(2000)	Dec.
April 1	14h49.6m		16°44'
April 6	14h46.7m		18°12'
April 11	14h43.4m		19°35'
April 16	14h39.7m		20°51'
April 21	14h35.7m		21°58'
April 26	14h31.7m		22°56'
May 1	14h27.6m		23°44'

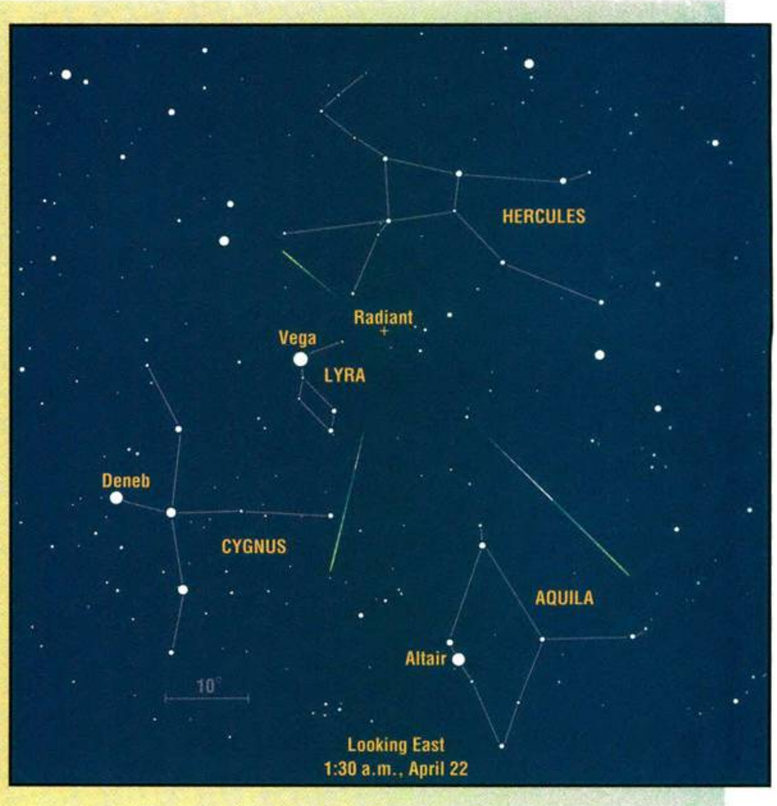
*For 11 p.m. EDT

The Lyrids Peak at New Moon

Although the Lyrid meteor shower is certainly not the best shower of 1996, there are several good reasons to catch it. One is that they peak shortly after this month's New Moon on April 21, which means moonlight will not wash out the sky. Another is this shower's tendency to pick up unexpectedly in activity. Although the Lyrids usually trickle in at 10 to 15 meteors per hour, the rate jumped to 100 per hour in 1982. Finally, this dependable shower has been witnessed by humans for at least 2,700 years. In fact, it was one of the first showers correlated with a comet, Comet Thatcher. The mathematician who found this correlation, J. A. Galle, suggested that the shower was active as early as March 15, 687 BC.

Your opportunity to glimpse this age-old shower happens on the night of April 21/22 (see "An April Shower," page 72). Face northeast, where Lyra rises, while keeping a sharp eye out between the zenith and the horizon. Look for short, fast meteors about magnitude 2 or 3 in brightness that appear to stream from a point southwest of Lyra's bright star Vega. The best time to watch is between midnight and dawn, when Earth's night side plows into the meteoroid stream. This increases the speed of incoming meteors and makes them burn brighter.

To get the most of any meteor observing session, bring along a recliner, warm clothing, a thermos of soup or coffee, binoculars (to observe any smoke trails), and of course, a friend or two. — *R. S.*



Looking East
1:30 a.m., April 22

Observer's Challenge:

Hunt Down a Quasar

Some observers hunt for certain nondescript celestial objects just to say they've seen them. Pluto is one, and the quasar 3C273 is another. While neither object is visually stunning (both are underwhelmingly faint and starlike), the real point is to see them and comprehend their historical importance.

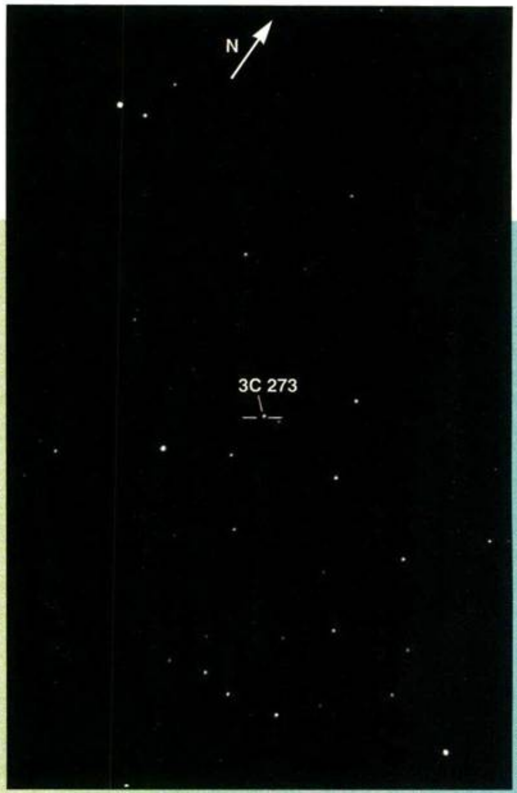
Pluto's relevance is obvious, but you might not know of 3C273's significance. After the Sun and the Galaxy, it was the first radio object found to correspond with a object visible through optical telescopes. 3C273 looks for all the world like a magnitude 12.8, very blue star. Hence the name "quasi-stellar radio source," or "quasar" for short.

In 1963 astronomers deduced that 3C273 was receding from us at enormous velocities. Hubble's theory of the expanding universe says the faster an object recedes, the farther away it is from Earth. Indeed, based on spectral analysis of the quasar's light, it's generally accepted that 3C273 is three billion light-years from Earth. To be that remote and visible at all, it must be a real powerhouse. (A normal galaxy might be expected to shine at magnitude 19 at 3C273's distance, not 12.8.)

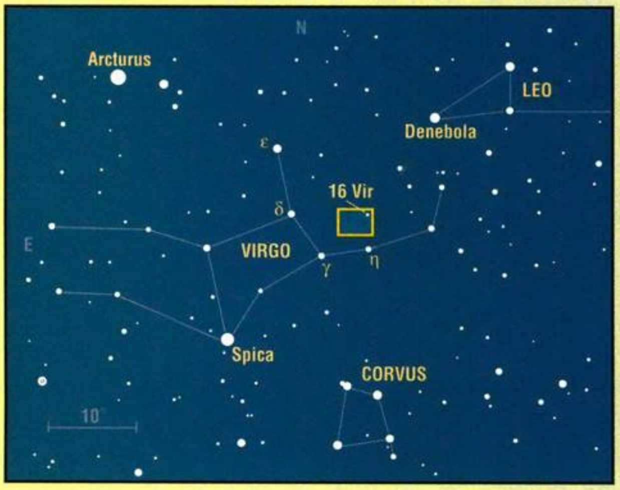
Although the exact nature of 3C273 is still at least somewhat mysterious (a supermassive black hole might be the culprit), its location is not. You can glimpse it through a telescope as small as 6 inches.

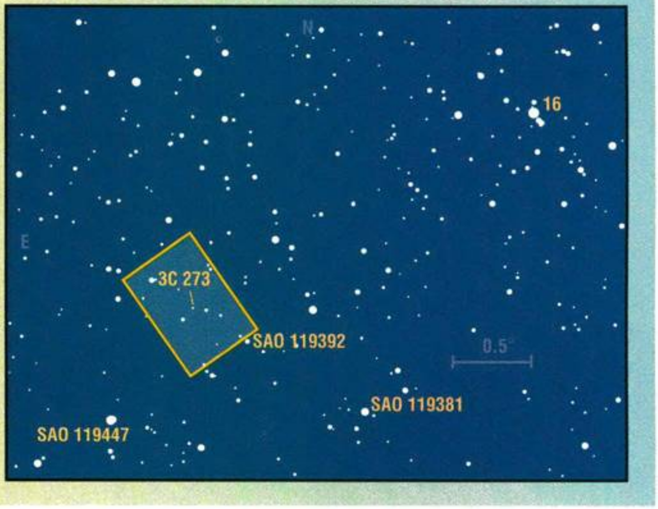
Begin the search by using binoculars to find 3C273's area just north of the stars Gamma and Eta Virginis (see wide-field diagram). Pan north of Eta to find the 5th-magnitude star 16 Virginis. Shift your gaze slightly southeast (both maps and the photo show north at the top) from 16 to a triangle made by two magnitude 7.6 and one magnitude 7.8 stars. Two of these stars, SAO 119447 and SAO 119392 mark the northeast leg of this triangle; 3C273's field lies roughly halfway between and slightly north of a line that connects these two stars (see diagram).

The photo pinpoints 3C273's position. After locating the quasar's field in a telescope at low power, raise magnification to 40x per inch of aperture to confirm its exact location. Once you've done this, step back and ponder 3C273's light that started a journey to Earth three billion years ago. — *R. S.*



Jack Newton





Moon makes Mercury an even easier target on April 19. Mercury's greatest elongation happens on April 23, when it is 20° east of the Sun on the sky's dome.

Long after twilight has left the western sky, shift your attention to the east where **Pluto**, the faintest planet, comes up around 10 p.m. This, the solar system's outermost planet, requires at least an 8-inch telescope to be seen.

Pluto's opposition comes next month, and finding it will be the topic of a feature story in ASTRONOMY's May issue.

If finding the solar system's faintest planet seems a tad difficult, wait a few hours for **Jupiter**, this month's second-brightest planet, to rise around 1 a.m. When Jupiter reaches opposition in July, it will rise as the Sun sets, as our Moon does on April 3. (The Moon reaches opposition once a month at Full Moon.)

During April, Jupiter lies in front of the constellation Sagittarius the Archer. The solar system's largest planet cannot be mistaken for anything else because it shines so brightly at magnitude –2.3. Look for it near the Last Quarter Moon on April 10. Jupiter's disk as seen through a telescope grows to a fabulous 40" across this month and swells even larger still by July's opposition.

Another gas giant planet, one about one-third the size of Jupiter, lies in Sagittarius: the planet **Neptune**. It shines at a faint magnitude of 7.9, too dim to be seen with the eye alone. But the best time of year to observe the tiny bluish disk of Neptune through a telescope is approaching. On April 29, the planet becomes stationary against the sky background. This phenomenon always happens when our planet is about to pass between the Sun and planets outside the orbit of Earth, which we will do with Neptune in July.

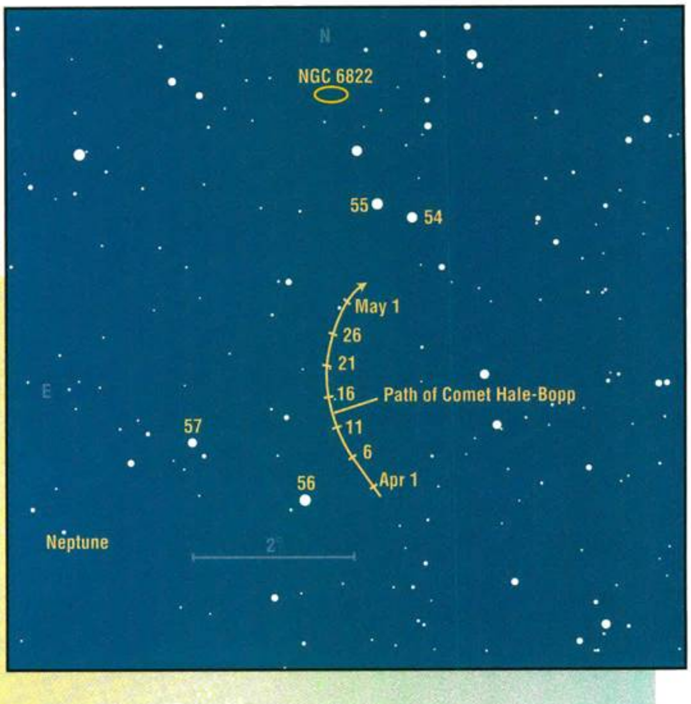
In nearby Capricornus the Seagoat lies **Uranus**. Both Uranus and Neptune rise in the wee hours this month. Along with its gas giant cousin, Uranus will reach opposition in July. In April it shines at magnitude 5.8, bright enough to glimpse with the naked eye from a dark site.

Our last gas giant, **Saturn**, rises too close to the Sun to be visible in early April, but as the month passes it creeps higher into morning twilight. It shines at magnitude 1.1 and lies in the constellation Pisces.

Look for Saturn on April 16 when it rests 4° south of a crescent Moon that's about two days before New. A view through a telescope shows that Saturn's rings are gradually opening after last year's edge-on appearance.

Finally, we greet the sunrise with Mars, which is still too close to the Sun to be seen. It returns to the predawn sky next month.

Hale-Bopp Rounds a Corner



COORDINATES FOR COMET HALE-BOPP*

Date	R.A.	(2000)	Dec.
April 1	19h42.8m		–19°36'
April 6	19h43.9m		–19°14'
April 1	19h44.7m		–18°52'
April 16	19h45.1m		–18°30'
April 21	19h45.2m		–18°07'
April 26	19h44.9m		–17°43'
May 1	19h44.1m		–17°20'

*For 5 a.m. EDT

This is the month Comet Hale-Bopp starts a slow turn to the west, putting it on track for a swing through the Milky Way this summer. All during April, the comet resides in a region less than 14° east of the Teapot's handle in Sagittarius.

One more milestone arrives this month when Comet H-B breaks the 8th-magnitude barrier. By month's end, it should shine as a magnitude 7.7 fuzzball just 2 ½° south of the irregular galaxy NGC 6822, "Barnard's Galaxy," in eastern Sagittarius.

Incidentally, at midmonth another celestial object identical in brightness to Hale-Bopp lingers about 3 ½° east of the comet: magnitude 7.9 Neptune. Both rise shortly after 2 a.m. local time, which gives observers in the middle latitudes a two-hour window of darkness before dawn.

One source of unwanted light, the Moon, hangs in the morning sky the first two weeks of April, until reaching New Moon on the 17th. Under a dark sky, the comet should be just within the grasp of 7x50 binoculars. For better views, use at least a 4-inch scope.

Since Hale-Bopp's nucleus is so large (more than 120 miles in diameter, 20 times that of Comet Halley), a high-power view might show jets of gas coming from the nucleus. Conduct your own jet search with an eyepiece that yields 200x; don't be afraid to apply even higher power if you're observing with a 16-inch or larger telescope.

If you do glimpse what you think is a jet, make a sketch and then come back an hour later to make another sketch. The two drawings should show the candidate jet as it evolves over time. — *R. S.*

Farewell to Friends

It's with mixed feelings that I say good-bye to my friends, the readers of ASTRONOMY. After writing this column for nearly a decade, it's time to turn the task over to another pair of capable hands. Your letters and comments this column has generated over the years have been a greater source of delight than I can express. Providing the sky to you gave me good reason to sit down and form a mental picture of what the night held for the future. Even though I'll still be writing about the sky for the "Earth & Sky" radio series I help produce, it will be in bits and pieces. The heaven will demand less of my time. Now there will be a few extra hours each month to talk with my husband and two daughters, tend our garden, take longer walks and, as always, keep both eyes and all my heart open to the sky. — *Deborah Byrd* ☐

Deborah Byrd writes and produces the daily "Earth and Sky" radio series. Rick Shaffer is an engineer and writer living in Arizona.

by Ronald W. Kohl

Galaxies On Edge

A moderate-sized telescope shows dozens of needle-thin spiral disks aligned edge-on to our line of sight.

NGC 4565 in Coma Berenices

There's something special about edge-on galaxies. Aligned with their sharply defined edges directed toward our line of sight, they appear to be glowing needles in the sky. Perhaps the attraction lies in their razor-sharp forms, which stand in marked contrast to the decidedly fuzzy appearances of most galaxies.

Whatever the allure, springtime is the best time to target edge-on galaxies. Not only is the best overall selection of galaxies visible in the spring evening sky, with the Milky Way rolled over so telescopes can view beyond it, but it seems the best edge-on galaxies show themselves this time of year.

Edge-on galaxies offer a peculiar observational advantage over those oriented face-on toward Earth. Imagine two galaxies at the same distance and with the same brightness and size, one face-on and one edge-on. The face-on galaxy appears to cover more sky, so its brightness spreads over a larger area. The edge-on galaxy covers a smaller area of sky, and therefore its surface brightness — its brightness per unit area of sky — is higher. Because of this, observers can spot edge-on galaxies out to much greater distances than their face-on counterparts.

Armed with a fascination of edge-on galaxies, I set out to image a few with my 20-inch Cassegrain telescope, a Star I CCD camera, and exposures ranging from 3 to 6 minutes. I shot all of the CCD frames from my observatory in Lakewood, New York, and processed them using IP Lab/Spectrum software.

Though I used a large, permanently mounted telescope to image these edge-on galaxies, observing them is easy and requires only a modest telescope. The brightest galaxies described in this article can be seen with a 6-inch telescope; the faintest ones require a 10-inch scope.

You can find these galaxies with a star atlas like *Sky Atlas 2000.0* by Wil Tirion (Cambridge University Press and Sky Publishing Corp.), *Cambridge Sky Atlas 2000.0* by Wil Tirion (Cambridge University Press), or *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi (Willmann-Bell).

When the sky darkens and the stars come out on an April evening, many edge-on galaxies are already strategically placed for observing. If you can catch it quickly before it slips under the horizon, try aiming at **NGC 891** in Andromeda, low in the northwestern sky. This 10th-magnitude Sb-type galaxy is roughly similar to the Milky Way and lies 30 million light-years away.

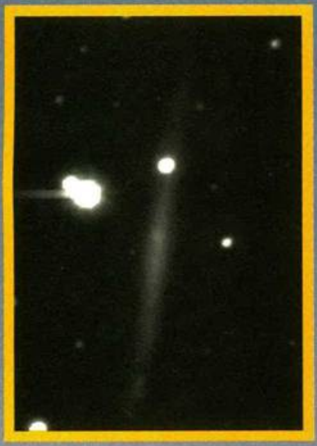
The galaxy appears rather faint in the eyepieces of most telescopes, although an 8-inch or larger instrument under dark skies reveals NGC 891's broad equatorial dust lane. Try to detect the galaxy's central bulge and a few faint stars that lie adjacent to it.

A number of galaxies sprinkled along the fringes of the winter Milky Way, low in the northwest, also await your gaze. Two such galaxies in Perseus are **NGC 1175** and **NGC 1465**. Both are faint and small, appearing in 12-inch telescopes as a central glow with wings of extremely faint light comprising the edge-on disks. These galaxies are spirals that lie farther away than NGC 891: NGC 1175 is 240 million light-years distant, NGC 1465 some 100 million light-years off.

A similarly faint and challenging edge-on spiral lies in nearby Cepheus, **NGC 1184**. This galaxy has a relatively easy-to-spot central fuzzball and a thin disk that stands up better to high magnification than those of the previous two galaxies. The distance to NGC 1184 is uncertain.

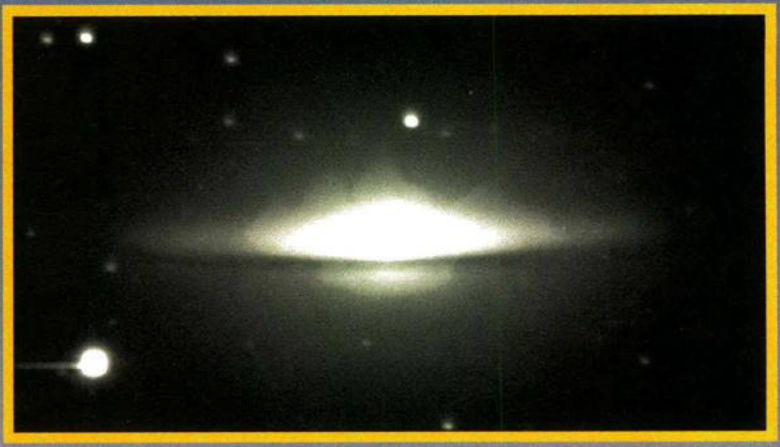
As evening begins to mature, try spotting three edge-on wonders in the northern constellation Camelopardalis. **NGC 1469**, **NGC 1485**, and **NGC 1560** are relatively challenging galaxies for small telescopes, particularly the first two. NGC 1469 is a faint lenticular galaxy that sits in a pretty field of stars, including a bright one close to the galaxy. Its distance is uncertain.

NGC 1485, a magnitude brighter than NGC 1469, is probably an Sb-type spiral like the Milky Way. Its distance, too, is not yet determined. A beautiful faint foreground star sits in *front* of a portion of this galaxy's spiral disk. If the last few galaxies



IC 2233 in Lynx

M102 in Draco



The Sombrero Galaxy (M104) in Virgo

All images by Ron Kohl, made with a 20-inch Cassegrain, a Star I CCD camera, and exposures ranging from three to six minutes.

have seemed frustratingly faint, try NGC 1560, an Sd-type galaxy whose wispy, ghostlike disk spans nearly 10'. This low luminosity galaxy is a neighbor, lying a mere 7 million light-years away.

More edge-on galaxies lie scattered through Camelopardalis and the neighboring constellations Lynx and Ursa Major. Follow them by progressing eastward around the pole. A treat awaits you in Lynx's **IC 2233**, one of the thinnest galaxies observable in backyard telescopes. This 13th-magnitude spindle measures 4.7' by 0.6'. It is the soft light of a barred spiral oriented almost exactly edge-on. This galaxy lies a modest 25 million light-years away.

A much closer and brighter spiral, also in Lynx, is **NGC 2683**. Brighter than 10th magnitude, this galaxy may be viewed in a 4-inch telescope. It is a classic edge-on galaxy, with a bright nucleus and a razor-sharp disk, whose misty light travels across a gulf of 10 million light-years. Two more edge-on spirals located nearby in Camelopardalis are **NGC 2732** and **NGC 2748**, distant spirals that constitute a challenge for small scopes.

By midevening under an April sky, the Big Dipper stands high overhead. Three of the finest edge-on galaxies in the sky reside in the Big Dipper's constellation, Ursa Major. The brightest is the iconic **M82** (NGC 3034), an 8th-magnitude irregular galaxy that offers great detail for small scope users. The galaxy's thin, bright disk backlights an intricate network of dark nebulosity seen projected against the galaxy's light. The whole disk of bright and dark appears encased in a smooth halo of very faint, gray-green light. Telescopes as small as 8 inches reveal some of the dark nebulosity on dark nights; it's routinely visible in 12-inch and larger scopes. M82 is part of the Ursa Major cloud of galaxies, lying some 17 million light-years away. (Be sure to see the bright spiral M81, less than a degree south of M82.)

Ursa Major's other edge-on spirals are bright enough for small scopes, too. **M108** (NGC 3556) glows at magnitude 10 from a distance

Galaxies in Cyberspace

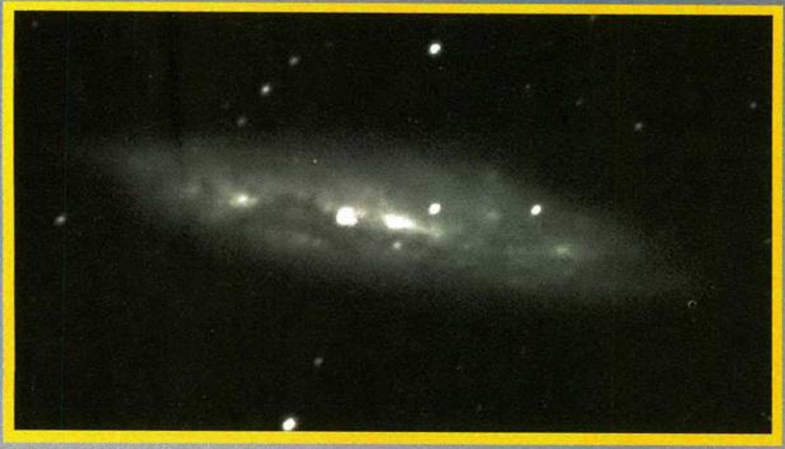
Many sites on the Internet provide information on galaxies and even images of them. Here are a few notable places to visit:

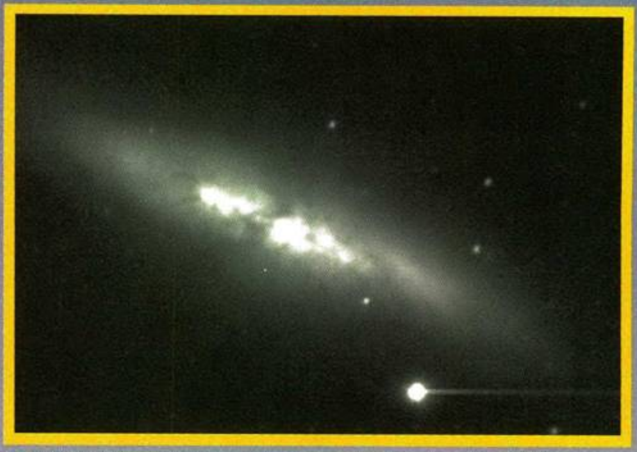
CCD Images of Galaxies. Operated by the University of Oregon's Pine Mountain Observatory, this site features plentiful images of well-known and obscure galaxies. http://zebu.uoregon.edu/galaxy.html

Galaxies. The University of Arizona's site contains images of Messier galaxies. Great fun for hunters of bright galaxies. http://seds.lpl.arizona.edu/messier/galaxy.html

The Galaxy Catalog. Princeton University's Zsolt Frei assembled this collection of digitized images of 113 galaxies. Downloadable. Provides hours of enjoyable scanning and image play. http://astro.princeton.edu/~frei/galaxy_catalog.html

Star Formation in Galaxy Mergers. Excerpts from a paper by J. Christopher Mihos and Lars Hernquist offer superb graphics of a galaxy merger over time. http://zeus.ncsa.uiuc.edu:8080/BlueBook96/Galaxies.html


M108 in Ursa Major


M82 in Ursa Major

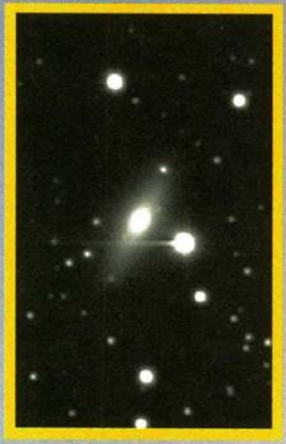
How to Find It

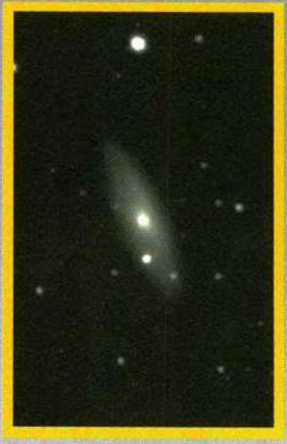
These star atlases will help you find edge-on galaxies:

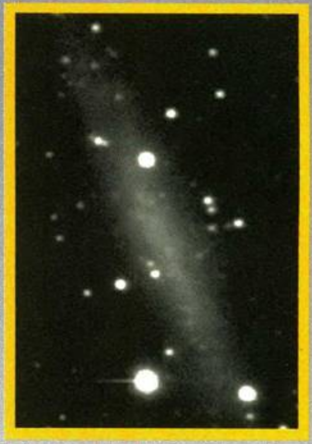
Cambridge Star Atlas 2000.0 by Wil Tirion (Cambridge University Press, New York, 1992). Beginning.

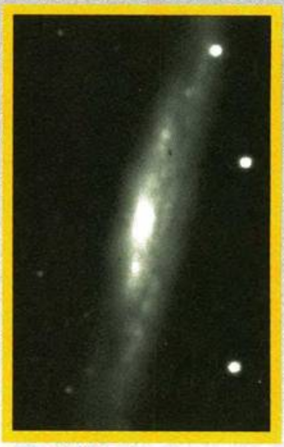
Sky Atlas 2000.0 by Wil Tirion (Sky Publishing Corp. and Cambridge University Press, Cambridge, Massachusetts, 1981). Intermediate.

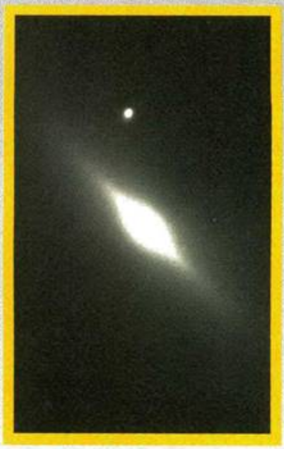
Uranometria 2000.0 by Wil Tirion, Barry Rappaport, and George Lovi (Willmann-Bell, Richmond, Virginia, 1987–1988). Advanced.


NGC 1469 in Camelopardalis


NGC 1485 in Camelopardalis


NGC 1560 in Camelopardalis


NGC 3079 in Ursa Major


NGC 3115 in Sextans

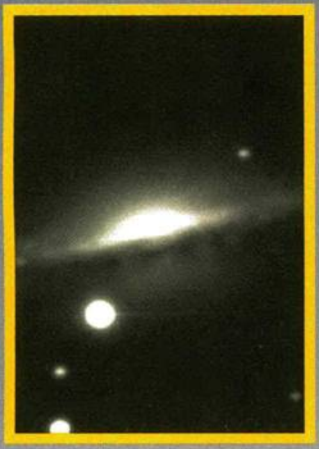
of 34 million light-years. Though it is more distant than M82, M108 also shows a mottled network of dark nebulosity in front of the galaxy's disk, detectable in an 8-inch scope. A bright star near the galaxy's center is not a supernova — it's a Milky Way star far in the foreground.

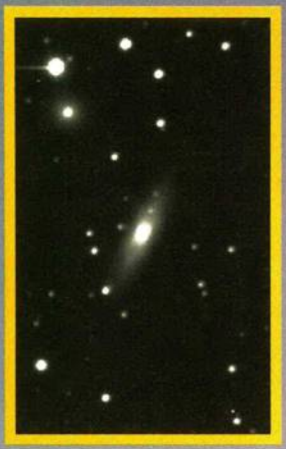
NGC 3079, a magnitude 10.6 spiral west of the Dipper's bowl, reveals its slender form to scopes as small as 4 inches. This galaxy is a more distant target, at a range of about 50 million light-years.

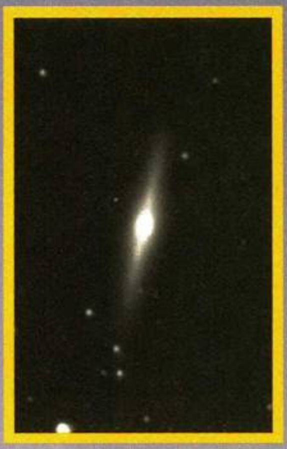
South of the Dipper, the constellations Leo, Leo Minor, and Sextans hold some pretty impressive examples of edge-on galaxies. These include **NGC 3115** in Sextans, **NGC 3432** in Leo Minor, and **NGC 3628** in Leo. NGC 3115 and NGC 3628 are impressive objects for nearly any telescope.

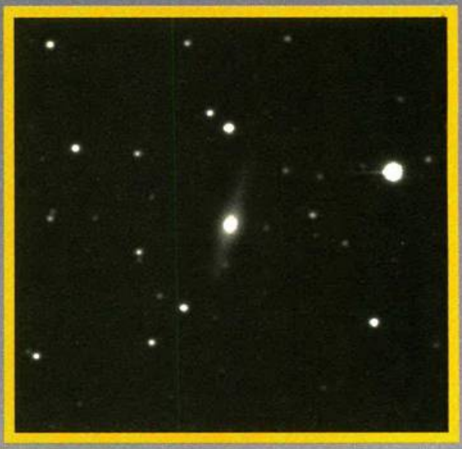
NGC 3115 has a bright, egg-shaped central bulge with an extremely thin disk bisecting it. It's a gorgeous sight at high power on a steady, transparent night. NGC 3628 shows a broad equatorial dust lane, visible in a 6-inch scope, and a wide, curvy disk that reminds one of a warped LP record.

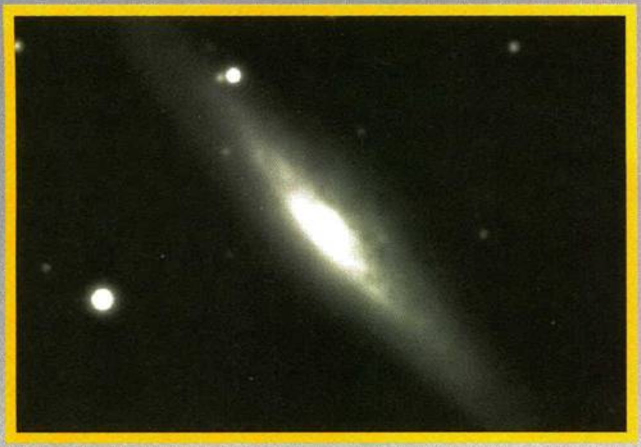
East of this region, the great Realm of the Galaxies stretches over Virgo and Coma Berenices. *In this direction we see far more galaxies than in any* other: It's a relatively unobscured area away from the plane of the Milky Way, and the greatest cluster of galaxies in our neighborhood of the universe sprawls out in this direction. Consequently, many

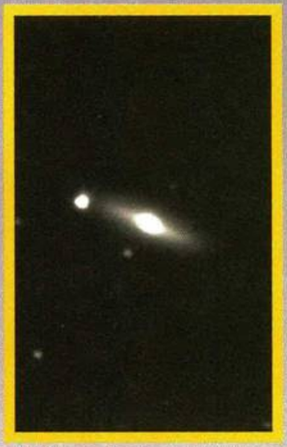

NGC 1055 in Cetus

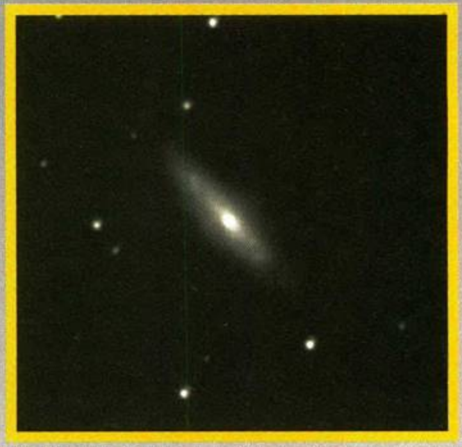

NGC 1175 in Perseus

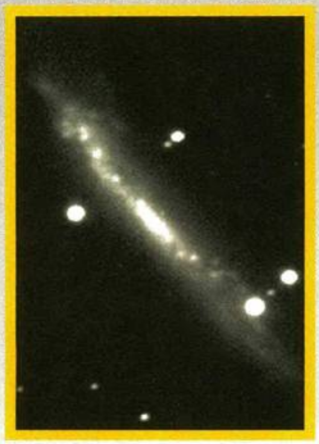

NGC 1184 in Cepheus

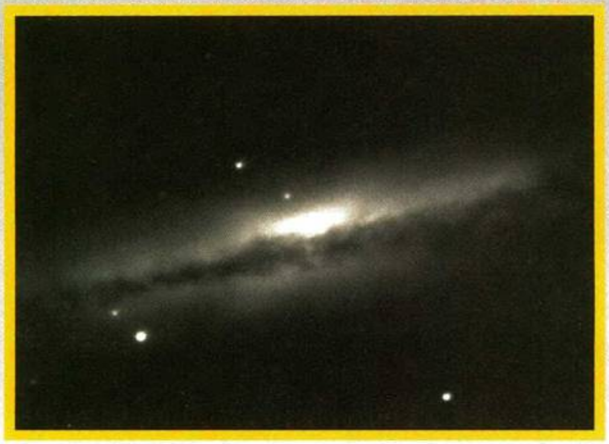

NGC 1465 in Perseus

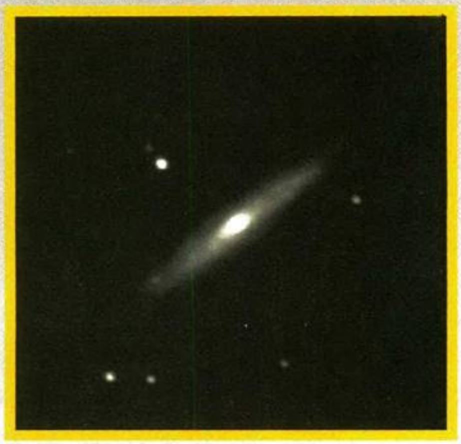

NGC 2683 in Lynx


NGC 2732 in Camelopardalis


NGC 2748 in Camelopardalis


NGC 3432 in Leo Minor


NGC 3628 in Leo


NGC 3735 in Draco

examples of edge-on galaxies may be found in the region.

The quintessential edge-on galaxy, **NGC 4565** in Coma Berenices, forms a fine sight in any telescope. It appears as a thin needle of light with a bulbous knot in the center and an exquisitely thin dust lane running the whole length of the galaxy. The galaxy lies 50 million light-years away. Also not to be missed, the **Sombrero Galaxy** (M104, NGC 4594) in Virgo offers the greatest example of a galaxy that appears like a spacecraft from a fifties B movie.

The bright central glow rests on a thin wedge of dark lane extending across the whole galaxy, and the whole image is cocooned in a faint halo of light that provides a surreal result. The Sombrero is a bit closer than NGC 4565, at 42 million light-years. Other outstanding examples of

NGC 4216 in Virgo

NGC 4217 in Canes Venatici

NGC 4236 in Draco

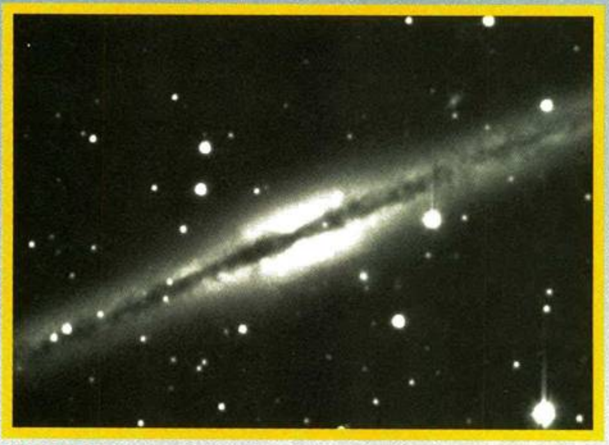
NGC 5907 in Draco

NGC 5908 in Draco

NGC 7814 in Pegasus

NGC 7332 and **NGC 7339**

NGC 4298 and **NGC 4303** in Coma Berenices


NGC 891 in Andromeda

edge-on galaxies in the area include **NGC 4216**, **NGC 4298**, **NGC 4302**, and **NGC 5746**.

Climbing north to Canes Venatici unveils more examples. One of the oddest edge-on galaxies must be **NGC 4631**, a big, 9th-magnitude, Sc-type galaxy. The galaxy's whole disk appears mottled with dust clouds, giving observers the impression that it's been fractured into uncountable pieces. The little galaxy NGC 4627, interacting with NGC 4631, lies adjacent to the bigger spiral. The pair lies close by, at 27 million light-years. Also in this small constellation are the edge-on galaxies **NGC 4217** and **NGC 4244**.

By midnight, the sinuous form of Draco crawls into prominence in the northern sky. Draco's fine set of edge-ons includes two outstanding examples, **M102** (NGC 5866) and **NGC 5907**. A 10th-magnitude glow in small scopes, M102 consists of a bright center, a tiny, difficult dark lane, and an oval-shaped disk that's easy to see in a 6-inch scope at high power. NGC 5907, on the other hand, is a poor man's version of NGC 4565: a classic, edge-on needle, just not quite so big and bright. Other great examples in Draco include **NGC 3735**, **NGC 4236**, and **NGC 5908**.

Having finished Draco, you may wish to pack it in. A few more galaxies creep into visibility just before dawn, however, if you're inclined to hunt them down. Or, you may wish

NGC 4244 in Canes Venatici

NGC 4631 in Canes Venatici

in Pegasus

to wait a month or three until the sky rolls around and brings them into better view. These include **NGC 7332**, **NGC 7339**, and **NGC 7814** in Pegasus, and **NGC 1055** in Cetus.

Without these last few, however, the sky offers a hefty group of 28 exceptional edge-on galaxies to explore. Many others can be found in various observing guides. Discovering the sleek beauty of these systems will provide hours of observing enjoyment. ☐

Ron Kohl is an orthodontist and has enjoyed amateur astronomy for more than 40 years. His astronomical images have appeared in Newsweek *and* The New York Times.

Bright Edge-On Galaxies

Galaxy	R.A.(2000.0)Dec.	Mag.	Size	Con.
NGC 7814	0h03.3m +16°09'	10.5	6.3' by 2.6'	Peg
NGC 891	2h22.6m +42°21'	10.0	13.5' by 2.8'	And
NGC 1055	2h41.8m +0°26'	10.6	7.6' by 3.0'	Cet
NGC 1175	3h04.5m +42°20'	12.8	2.1' by 0.7'	Per
NGC 1184	3h16.6m +80°48'	13.4_P	2.6' by 0.7'	Cep
NGC 1465	3h53.6m +32°28'	—	1.7' by 0.5'	Per
NGC 1469	4h00.5m +68°35'	14.5_P	2.1' by 0.7'	Cam
NGC 1485	4h05.1m +71°00'	13.6_P	2.2' by 0.7'	Cam
NGC 1560	4h32.8m +71°53'	11.5	9.2' by 1.7'	Cam
IC 2233	8h14.0m +45°44'	13.0	4.7' by 0.6'	Lyn
NGC 2683	8h52.7m +33°25'	9.7	8.4' by 2.4'	Lyn
NGC 2732	9h13.4m +79°11'	11.9	1.8' by 0.8'	Cam
NGC 2748	9h13.7m +76°29'	11.7	2.8' by 1.1'	Cam
M82 (NGC 3034)	9h55.8m +69°41'	8.4	11.2' by 4.6'	UMa
NGC 3079	10h02.0m +55°41'	10.6	7.6' by 1.7'	UMa
NGC 3115	10h05.2m –7°43'	9.2	8.3' by 3.2'	Sex
NGC 3432	10h52.5m +36°37'	11.3	6.2' by 1.5'	LMi
M108 (NGC 3556)	11h11.5m +55°40'	10.1	8.3' by 2.5'	UMa
NGC 3628	11h20.3m +13°36'	9.5	14.8' by 3.8'	Leo
NGC 3735	11h36.0m +70°32'	12.2_B	4.2' by 1.0'	Dra
NGC 4217	12h15.8m +47°06'	11.9_B	5.5' by 1.8'	CVn
NGC 4216	12h15.9m +13°09'	10.0	8.3' by 2.2'	Vir
NGC 4236	12h16.7m +69°28'	9.7	18.6' by 6.9'	Dra
NGC 4244	12h17.5m +37°49'	10.2	16.2' by 2.5'	CVn
NGC 4298	12h21.5m +14°36'	11.4	3.2' by 1.9'	Com
NGC 4302	12h21.7m +14°36'	11.6	5.2' by 1.1'	Com
NGC 4565	12h36.3m +25°59'	9.6	16.2' by 2.8'	Com
M104 (NGC 4594)	12h40.0m –11°37'	8.3	8.9' by 4.1'	Vir
NGC 4631	12h42.1m +32°32'	9.3	15.1' by 3.3'	CVn
NGC 5746	14h44.9m +1°57'	10.6	7.9' by 1.7'	Vir
M102 (NGC 5866)	15h06.5m +55°46'	10.0	5.2' by 2.3'	Dra
NGC 5907	15h15.9m +56°20'	10.4	12.3' by 1.8'	Dra
NGC 5908	15h16.7m +55°25'	11.9	3.2' by 1.3'	Dra
NGC 7332	22h37.4m +23°47'	11.0	4.2' by 1.3'	Peg
NGC 7339	22h37.8m +23°47'	12.1	3.0' by 0.9'	Peg

This table provides **right ascension** and **declination** in epoch 2000.0 coordinates; **V magnitude** (except a subscript B, which denotes a B magnitude; or a P, which denotes photographic magnitude); **size** in arcminutes; and the **constellation** that contains the galaxy.

an april Shower

The meteor-hunting season begins this month with a fairly modest but sometimes surprising shower – the April Lyrids.

by Philip M. Bagnall

As spring arrives in the Northern Hemisphere, the attentions of many backyard observers return to the sky. Gone are the frigid nights of winter, when a cozy house or apartment frequently proves too strong a lure. The lengthening days of spring bring warmer temperatures and often less cloudy skies, prime incentives for getting out to soak up the grand vistas afforded by a starry night.

Those grand vistas will be peppered with streaks of light after mid-April, as 1996's first good meteor shower reaches its peak. The Lyrid shower commences around April 16 and runs to the 25th, with the best time to observe coming between April 19 and 23. This year's maximum should occur on the afternoon of April 21 in North America, on that evening in Europe, and on the morning of the 22nd in Asia. This timing favors observers in Asia because, like most meteor showers, the Lyrids are best after midnight. Nevertheless, people in North America and Europe should still see a nice display before dawn on April 22.

In a typical year, about ten Lyrid meteors per hour can be seen from a dark site before morning twilight begins. Occasionally, however, the shower becomes a genuine downpour, raining nearly 100 meteors per hour (most recently in 1982).

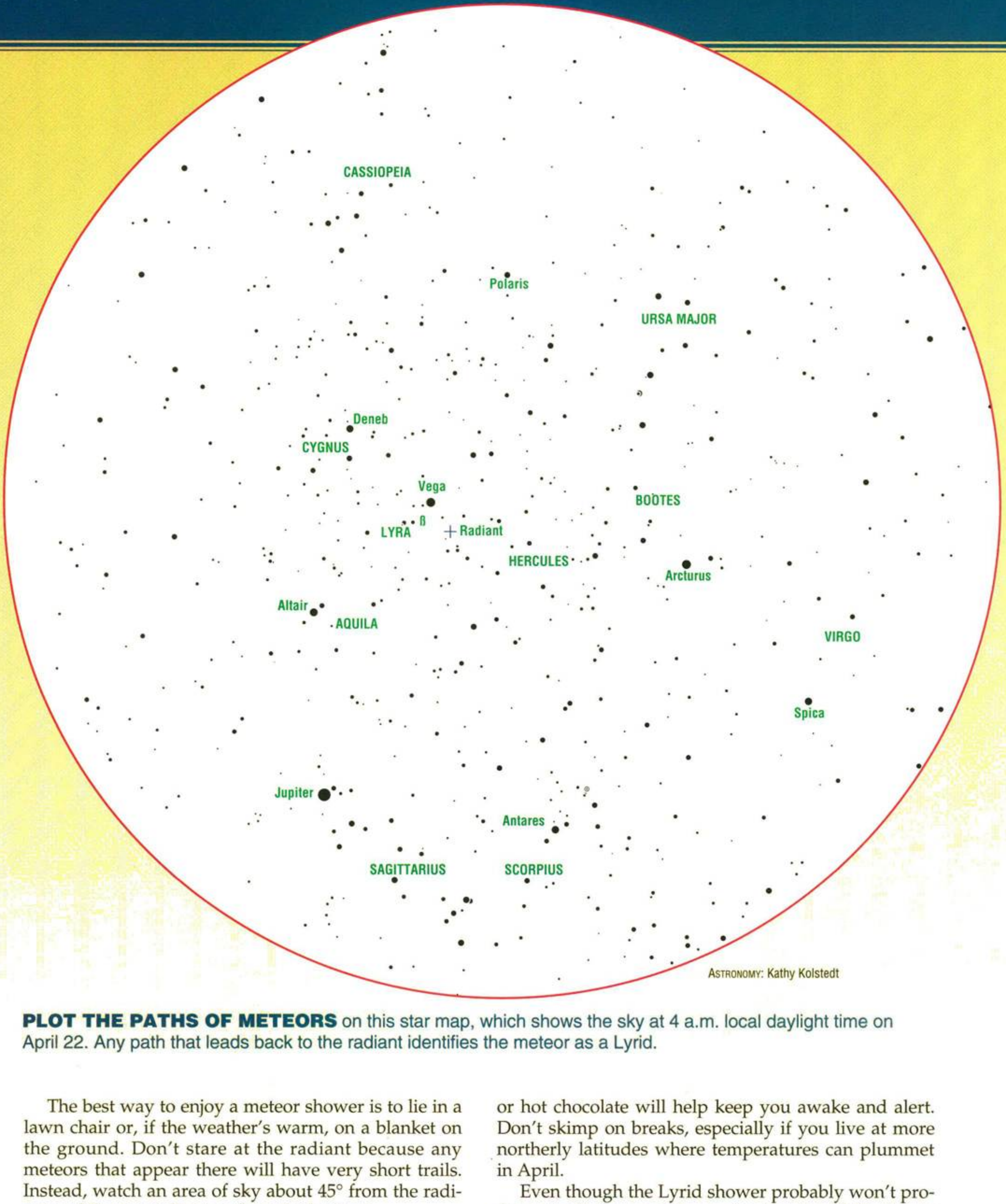
The Lyrids appear to radiate from a point near the 3rd-magnitude star Beta Lyrae (the shower takes its name from the constellation Lyra). But the radiant actually lies closer to 5th-magnitude 104 Herculis and, technically, resides in the constellation Hercules at maximum. Although the meteors seem to emanate from the radiant, that's just an optical illusion. They actually travel along nearly parallel trajectories, appearing to converge to a point on the celestial sphere in the same way parallel railroad tracks appear to converge at a point on the horizon.

Lyrid meteors zip into our atmosphere at about 48 kilometers per second, somewhat faster than average, and burn up at altitudes between 107 and 87 km. A typical Lyrid glows at 2nd magnitude and lasts about half a second, though roughly 15 percent leave behind persistent trains that can last anywhere from a few seconds to a couple of minutes.

The number of meteors you'll see depends strongly on local sky conditions. The ten-meteors-per-hour estimate holds if the radiant lies near your zenith and the sky is dark enough to reveal stars down to magnitude 6.5. The closer the radiant to your horizon, the fewer meteors you will spot, so observe when Lyra is highest shortly before twilight begins. Fortunately the Moon is only four days old on April 22 and does not interfere after midnight.

George Zay

LYRID OR SPORADIC? Although this meteor flashed during the peak of the 1994 shower, its long path so near the radiant shows it to be a sporadic.



ASTRONOMY: Kathy Kolstedt

PLOT THE PATHS OF METEORS on this star map, which shows the sky at 4 a.m. local daylight time on April 22. Any path that leads back to the radiant identifies the meteor as a Lyrid.

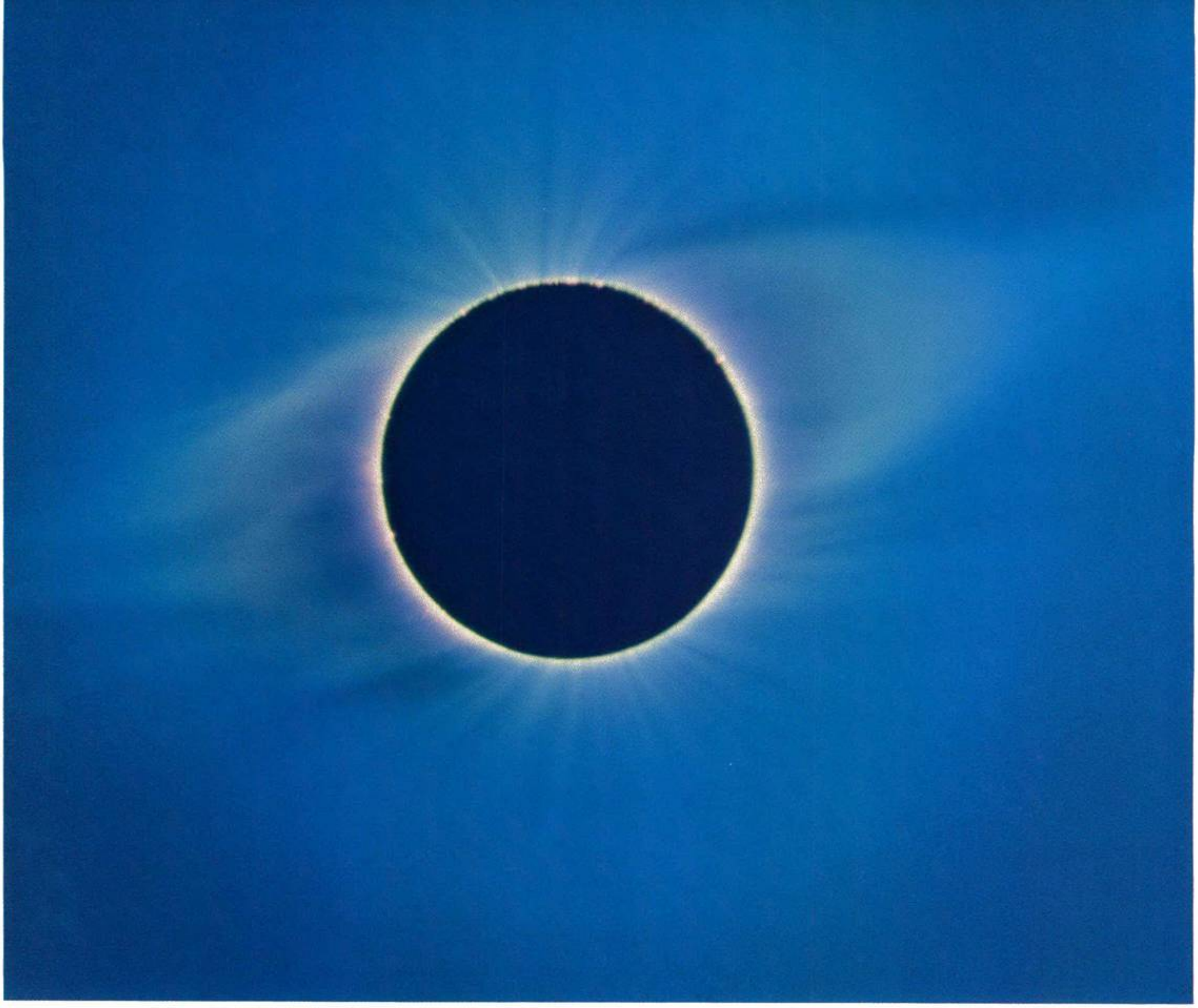
The best way to enjoy a meteor shower is to lie in a lawn chair or, if the weather's warm, on a blanket on the ground. Don't stare at the radiant because any meteors that appear there will have very short trails. Instead, watch an area of sky about 45° from the radiant and the same distance from the horizon.

When you see a meteor, memorize its path against the stars and plot it on the map above. If the path leads back to within a few degrees of the radiant, then you probably saw a Lyrid, otherwise it is a sporadic meteor. You may also want to estimate the meteor's magnitude by comparing it with nearby stars and record the time and duration of its train.

Try taking a ten-minute break after each hour of observing. Something to eat and a mug of coffee, tea, or hot chocolate will help keep you awake and alert. Don't skimp on breaks, especially if you live at more northerly latitudes where temperatures can plummet in April.

Even though the Lyrid shower probably won't produce prodigious numbers, viewing it will likely stir your observing juices, getting you ready for the balmy nights of spring and summer. And just as important, you'll gain valuable experience for August's great meteor shower, the Perseids, which comes this year during the dark of the Moon. □

Philip M. Bagnall has profiled several meteor showers for ASTRONOMY, most recently the Orionids in October 1995.



Alberto Levy

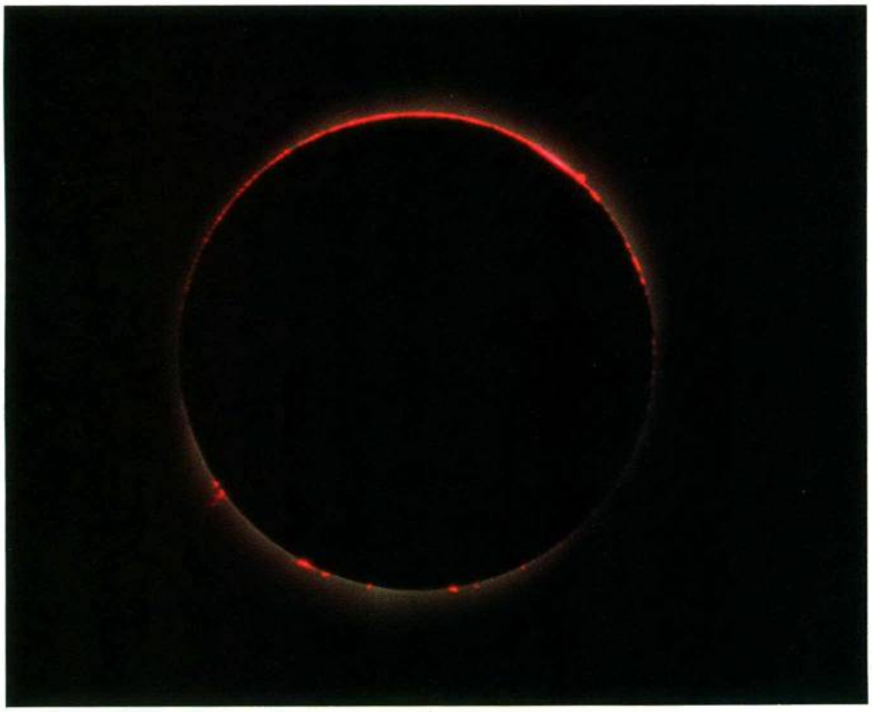
SPECTACULAR DETAIL IN THE SOLAR CORONA emerges when a photo of last October's eclipse is printed using a contrast-enhancing method called unsharp masking. The coronal plumage extends more than a solar diameter on either side of the Sun.

Surapong Pinijkhar

THE LIGHT AND SHADOW SHOW of last October's Asian total solar eclipse begins with a partially eclipsed Sun as the Moon encroaches, proceeds to totality, the diamond-ring effect as totality ends, and returns to partial stages as the Moon edges away from the Sun. Maximum duration for totality was 2 minutes, 10 seconds.

An Exotic Eclipse

by Jeff Kanipe



Hal Jandorf

THE CRAGGY LIMB OF THE MOON is silhouetted by the backlit hydrogen-red light of the chromosphere.

The Sun, a black-eyed Susan set amid the radiant petals of the corona; bright red prominences and sunlight playing along the Moon's limb; a privileged strip of Earth plunged into premature twilight; the sky an electric rose; every face turned up in awestruck wonder.

These are the hallmarks of a total solar eclipse, a surreal, never-to-be-forgotten event no matter when or where it is seen. But as witnessed from the Orient, the cradle of eastern religion and philosophy, a solar eclipse must surely be considered exotic by western standards. All the more so, in fact, when you take into account that the noun "orient" often refers to the iridescent luster of a pearl.

The solar eclipse of October 24, 1995, couldn't have been more oriental. The path of totality cut through northern India, southern Burma, Thailand, Viet-

nam, Malaysia, then through the Celebes Sea between the southern region of the Philippines and Indonesia. From there, the path continued south and east through the Caroline Islands, a part of Micronesia in the south western Pacific Ocean.

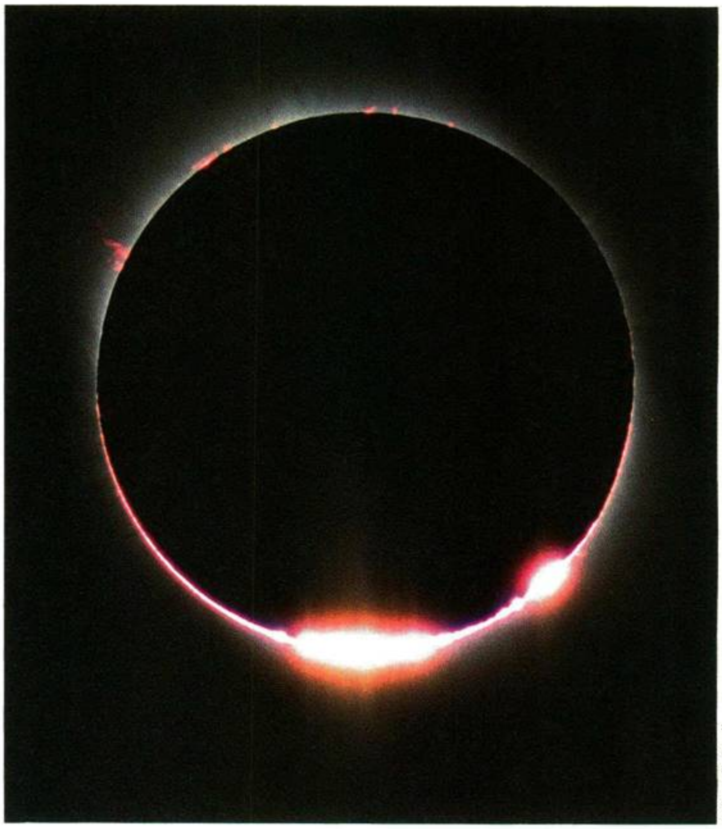
At it's widest, the path was only 78 km across, though it extended 13,600 km in length. As pointed out by eclipse veteran Fred Espenak of NASA's Goddard Space Flight Center in Greenbelt, Maryland, this amounts to less than a tenth of a percent of the total surface of Earth. Still, the event was witnessed by millions of people, many of whom traveled far and wide to stand for an all-too-brief time in the Moon's shadow.

ASTRONOMY received eclipse reports and photos from Indonesia, Japan, Germany, Canada, France, and Thailand, as well as the United States. Weather for the southwestern Pacific was quite good, and many observers reported bright prominences and spectacular views of the corona. The point of greatest eclipse occurred practically in the middle of the South China Sea west of the northern coast of Borneo, where totality lasted 2 minutes and 10 seconds.

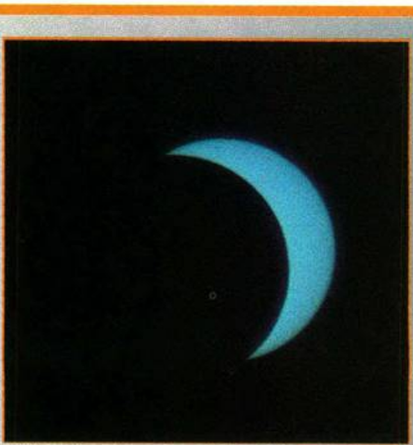
Farther west, Jordan L. Sutton of Everett, Wash., was observing with a group southeast of the town of Chon Buri, in eastern Thailand. "Shortly before second contact," he writes, "I began taking pictures [and continued] right through the 1 3/4 minutes of totality, and shot more photos of the growing crescent just after third contact. All the while, the horns on the 27 or so buses in the parking lot at the viewing site were being honked. Many firecrackers went off, and crowd cheers increased and continued until after the end of totality. Once the shouting ceased and most of the crowd had dispersed, our group celebrated a successful cloud-free viewing of the eclipse with a champagne toast."

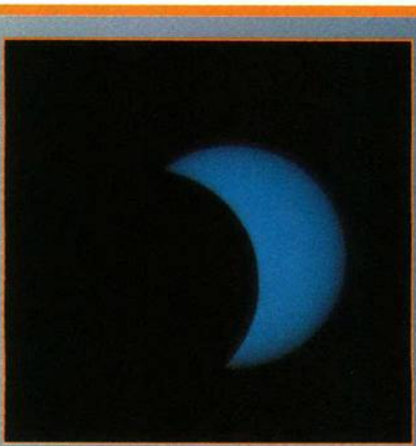
Herb Koenig, of San Diego, California, observed totality with his expedition group situated on the driving range of a golf course near Sikhiu west of Nakhon Ratchasima about three hours northeast of Bangkok, Thailand. "The most spectacular aspect of this eclipse," writes Koenig, "was the long equatorial streamers that extended at least one solar diameter in either direction."

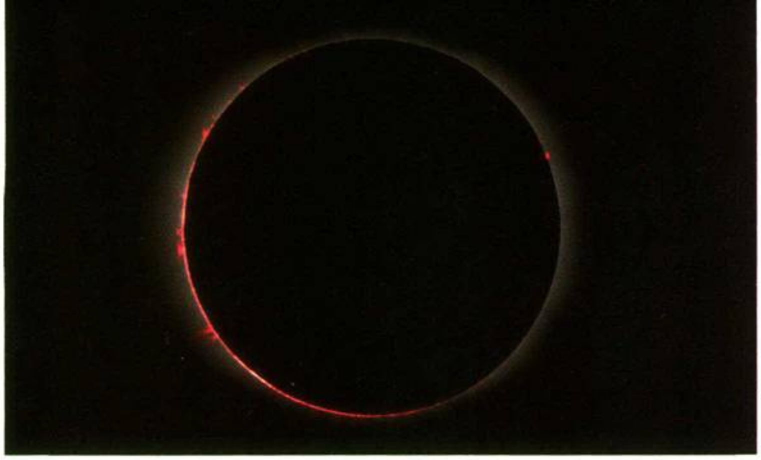
The viewing was no less impressive nearly 2,000


Jeffrey C. Buell

SUNSET BEHIND THE MOON. The last vestiges of sunlight shoot through several lunar valleys just before totality. A similar sight signaled the end of the totality, creating a double diamond-ring effect — or a very modest show of Baily's Beads.



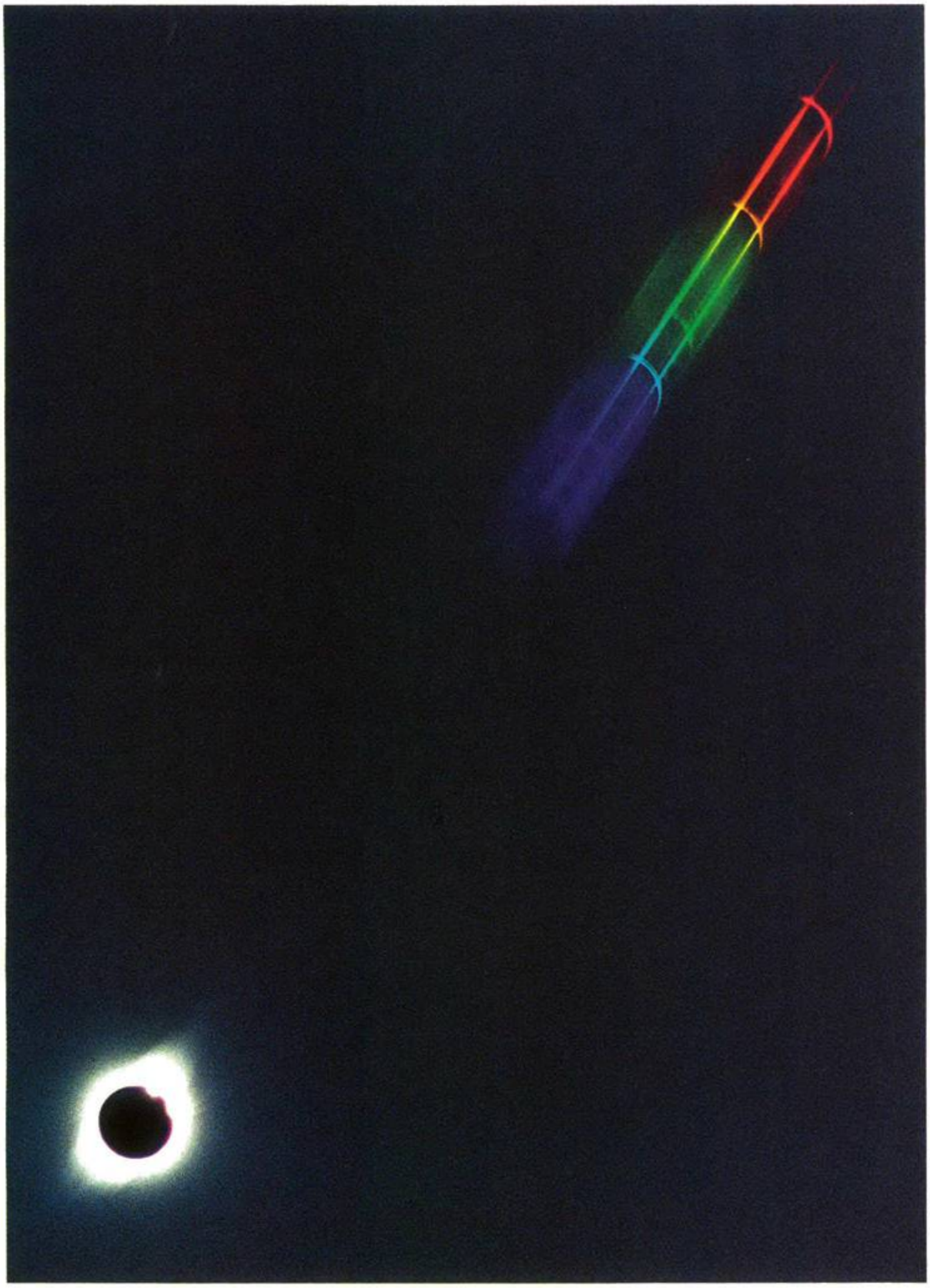




Jacques Guertin

A TOWERING PROMINENCE visible during totality extends more than 130,000 kilometers above the Sun's limb.

SEEN FOR ONLY A FEW SECONDS during totality, the emission spectrum of the solar chromosphere can be recorded, as it was here, by holding a diffraction grating in front of the camera lens and offsetting slightly from the Sun.



Robert B. Slobins/Phototake

thousand kilometers west in India, where Donald MacKinnon, of Saskatoon, Canada, noted two double-diamond rings. He was located in the state of Rajasthan, India, and so got in on the eclipse a little after 8 a.m. local time. "There was a double diamond ring at both second and third contact. I would be interested to learn how often two double diamond rings have been observed during the same eclipse."

Observing in the same vicinity of India, Jeff Buell and his eclipse group marveled at the limb action going on with both the Sun and Moon. "The chromosphere sliding in and out of the valleys and mountains of the Moon's northern limb were particularly spectacular. The prominences were unexpectedly numerous, with the tallest being only slightly shorter than the biggest seen during the 1991 eclipse."

A few people wrote to say that this was their first eclipse trip. Others claimed to have seen as many as two dozen already, and still hadn't gotten their fill. Testing the mettle of this exclusive group will be the next total solar eclipse, on March 9, 1997. It occurs in rather inaccessible regions of Mongolia, Siberia, and the Arctic Ocean. Exotic? Not exactly. Remote? Definitely. □

Jeff Kanipe is the managing editor of this magazine.

Hypercharge Your

Veteran astrophotographers coax stellar performances out of slower films to yield fine resolution and rich color.

Astrofilm

By John Shibley

Michael Stecker

Page after page in this magazine you come across photo after stunning photo of deep-sky objects. These fantastic pictures were taken by people who make astrophotography look so easy. Just how did they do it? Of course having the right telescope and photographic equipment was important, but just as crucial was using the right film.

Perhaps you've tried shooting a galaxy or nebula with film processed to speeds of ISO 800 to 3200, only to get results that lacked crispness and color, replete with grain the size of golf balls. Slower films saturate colors and offer higher contrast, but they're far too slow to use for deep-sky astrophotos, right? Wrong. For decades astroimagers have been turbocharging these slower films using a technique called film hypersensitization, better known as gas hypering.

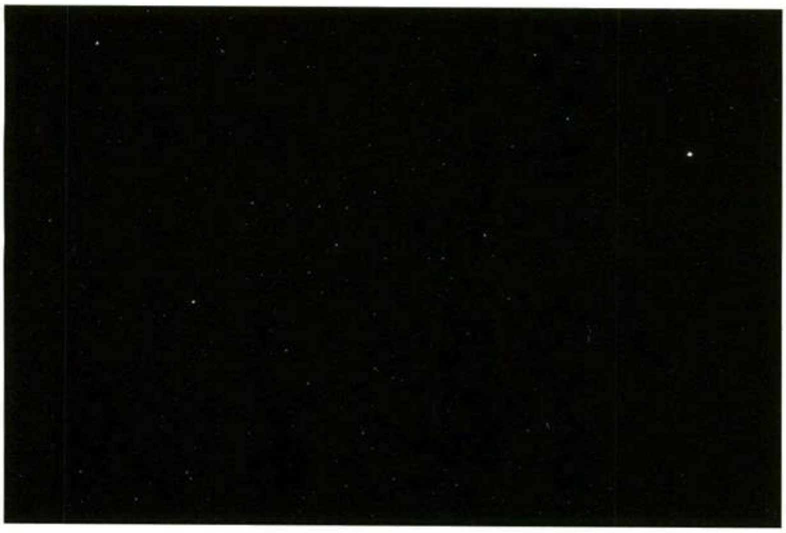
Go Soak It In Gas

Essentially, gas hypering aims to squeeze impurities out of film. The process places film into a tightly sealed container completely voided of air and heated to force out oxygen and moisture locked into the film's emulsion. After this "baking" step, a gas mixture composed of 92 percent nitrogen and 8 percent hydrogen is forced into the container from a gas tank. This so-called "forming gas" permeates the film and replaces the impurities. The net result: Film is better at recording images of very faint objects like galaxies and nebulae (see "Go Ahead, Make My Image," page 79).

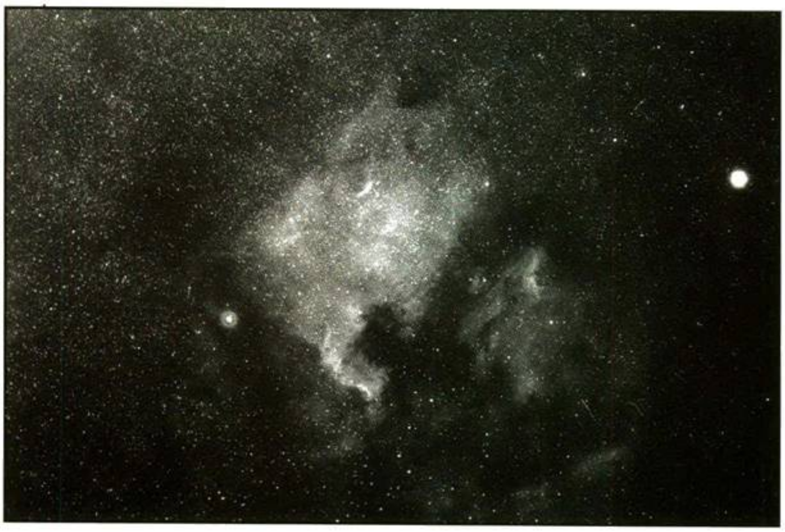
How much better? One extremely fine-grained black-and-film that's a favorite of astrophotographers, Tech Pan 2415, is ten times faster when hypered. Fujichrome RD100, for color slides, is anywhere from five to eight times more efficient.

Now if reading this leads you to conclude that you'll need to buy your own hypering equipment, you're only partly right. A company in California, Lumicon (2111 Research Drive #5A, Livermore, CA 94450, 510-447-9570), sells many popular types of astrofilms already hypered. The film comes in 12-,

A GAS CLOUD'S WISPY TENDRILS come alive in this stunning picture of the North American nebula taken on color film put through the gas hypering process. Purchase pre-treated film or make your own with a kit shown at the top of page 79.



Both photos by Jack Marling



DRAMATIC BENEFITS COME from hypering Kodak's Tech Pan 2415 black-and-white film. Where untreated film records nothing (top), hypered TP 2415 reveals a stunning North America Nebula (bottom). Both pictures are 15-minute exposures through a 5 ½-inch Schmidt camera fitted with a Wratten #92 red filter.

24-, and 36-exposure lots that range in price from $12 to $15.

Before you buy hypered film, though, bear in mind that it has limited storage life, and that each frame on a roll represents many minutes of astrophoto exposure time. With this in mind, buy only what you can shoot in two weeks, the deep-sky target window afforded by the Moon when it's not washing out the night sky.

But if you plan to take lots of deep-sky photos by piggybacking on or shooting through a telescope, perhaps buying a hypering kit seems reasonable. This option becomes all the more attractive if two people are willing to split its cost. Many astronomy clubs have purchased kits for use by members.

Do-it-Yourself Turbofilm

A typical hypering kit includes an airtight chamber that holds the film during treatment, a hand-operated vacuum pump to evacuate air from the chamber, a thermometer and pressure gauge, and a refillable gas cylinder loaded with forming gas.

Once again, Lumicon is the sole source for prefabricated kits. The cheapest, at $325, is their Model 300, capable of hypering one 35mm roll of film at a time. To process two 35mm rolls or one medium-format 120/220 roll at a time, consider the Model 600 (pictured on the opposite page) that sells for $395. Finally, if you crave the full-blown beauty of astrophotography on 4x5" or 5x7" sheet film, Lumicon sells the Model 1200 (which has two gas cylinders) for $595.

How often a hypering kit's gas cylinder needs refilling depends on what format of film is being treated at what temperature. Films with a greater surface area, such as 120/220 rolls and sheet film, absorb more gas. Treating films at lower temperatures also uses more gas because the hypering process takes longer. This gives the gas more opportunity to leak from the treatment chamber's less-than-perfect seal.

On the average, though, the Model 300 will treat 50 rolls of 35mm film before the gas tanks needs refilling, which costs about $35 if Lumicon does it. Buying forming gas from a local supplier in larger quantities might prove useful if you plan on treating a lot of film; look under "Welding Supplies" in the Yellow Pages.

Another very useful hypering accessory is a temperature controller that sells for $75 from Lumicon. It elevates and maintains the treating chamber's temperature between 45° and 55° C for more efficient hypering. Achieving a better vacuum in the chamber is also a plus, which is what an electric pump ($325) does. Of the two accessories, the temperature controller yields the most noticeable dividends, both in better pictures and less use of gas.

Astrophotography, Over Easy

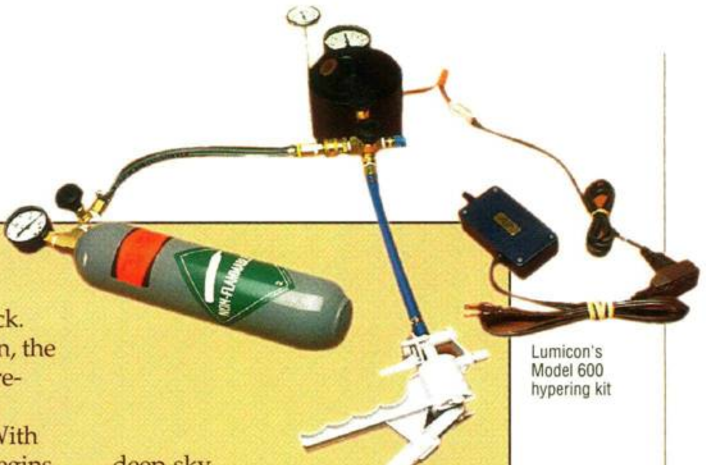
If all this equipment and consideration seems daunting, don't fret. Instructions that come with a hypering kit more than adequately explain hypering step-by-step for a variety of films astrophotographers find useful.

Typically, the process starts with you removing the film from its canister and loading it on a film processing reel in complete darkness, then placing the reel in the airtight treatment chamber. With the lights on, the next step is heating up the chamber and removing air with a hand pump or optional electric vacuum pump. Then the film "bakes" in a vacuum for about two hours before you add the forming gas.

Once the gas is added, the film bakes in its heated container for a time suggested in the kit's instructions. This step usually lasts between 10 and 160 hours, depending upon what temperature you're treating at and the type of film being treated.

After the baking process, remove the film from its treatment chamber in a completely darkened room. Load the treated film into a reusable film cassette, the

Go Ahead, Make My Image



Lumicon's Model 600 hypering kit

Film hypersensitization . . . how does it work? The answer lies in understanding why film sometimes fails during long-exposure astrophotography and how "hypering" solves the problem.

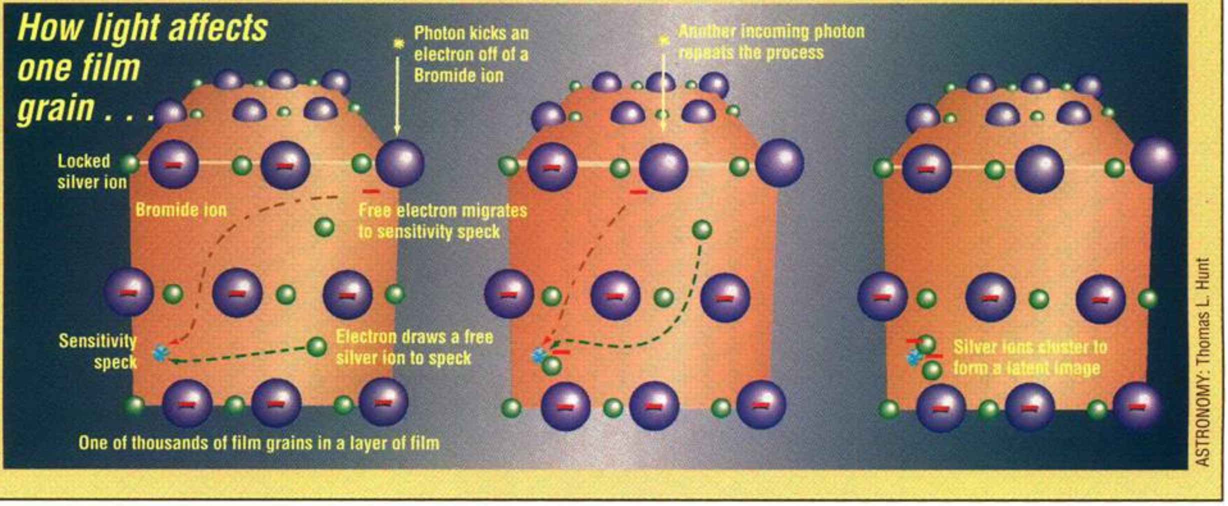
Film is made up of thousands of silver halide crystals, each containing three crucial players in the photographic process: silver bromide ions that carry electrons they desperately want to dump, free-roaming silver ions that wouldn't mind having those electrons, and several specks of silver sulfide, dubbed "sensitivity specks," where the two will meet. These three actors sit in complete darkness on the surface of film, just waiting for a photon of light to get the ball rolling.

When a photon of light does come along (when a camera's shutter opens), it strikes a silver bromide ion, letting it surrender the electron it's been carrying. The electron freely wanders the halide crystal until it bumps into a sensitivity speck. With this new-found electron, the sensitivity speck becomes irresistible to a silver ion, which eagerly binds to the speck. With this joining, a latent image begins to take shape, an image later developed by a photo lab into a slide or negative.

"Begins to take shape" is the operative phrase here, for no fewer than six silver ions must link up at one sensitivity speck to create a latent image. This must happen in a reasonable amount of time, say, a few seconds, or the speck begins to surrender the silver ions it's been hoarding.

In bright light, there are plenty of photons to trigger a cascade of electrons on a speck. But in dim light, like the light from a galaxy or nebula, it's another story. This is why it takes so long to shoot deep-sky objects: sensitivity specks get tickled, give back their ions, get tickled again . . . until finally they hang onto enough silver ions to form an image.

Hypering makes this whole process more efficient. Hypering uses a kit much like the one pictured above to squeeze out oxygen and water impurities from the film that compete for the free electrons and silver ions that wander a film grain during an exposure. As a result, the film is better at forming (and keeping) an image, especially images of very faint deep-sky objects.



How light affects one film grain . . .

Photon kicks an electron off of a Bromide ion
Another incoming photon repeats the process
Locked silver ion
Bromide ion
Free electron migrates to sensitivity speck
Sensitivity speck
Electron draws a free silver ion to speck
Silver ions cluster to form a latent image
One of thousands of film grains in a layer of film

ASTRONOMY: Thomas L. Hunt

kind photo stores sell to people who buy film in bulk. Store the cassette in a film can sealed with electrical tape to prevent air and moisture from seeping back into the film. For even more protection, slip the film can into a "zip-loc" storage bag and store it in the freezer.

Despite your best efforts, the world's air and moisture will still manage to leach back into hypered film over time. The most popular type of treated black-and-white film, Tech Pan 2415, has a freezer life of about a month. Most color emulsions, be they slide or negative, usually last about one or two weeks before reverting to their old state.

In the meantime, you've got film up to the task of capturing the universe in all its glorious detail and color, in a surprisingly small of time. After running that first roll of hypered film through a camera, you'll wonder how your world of astrophotography ever got by without it. ☐

John Shibley is an associate editor of ASTRONOMY *magazine who dabbles with hypered film when he can get away from the lights of metro-Milwaukee.*

A Window Into the Deep

Jump into *real* deep space by visiting a distant galaxy cluster some 500 million light-years away.

by Tom Johnston

The Hercules Galaxy Cluster

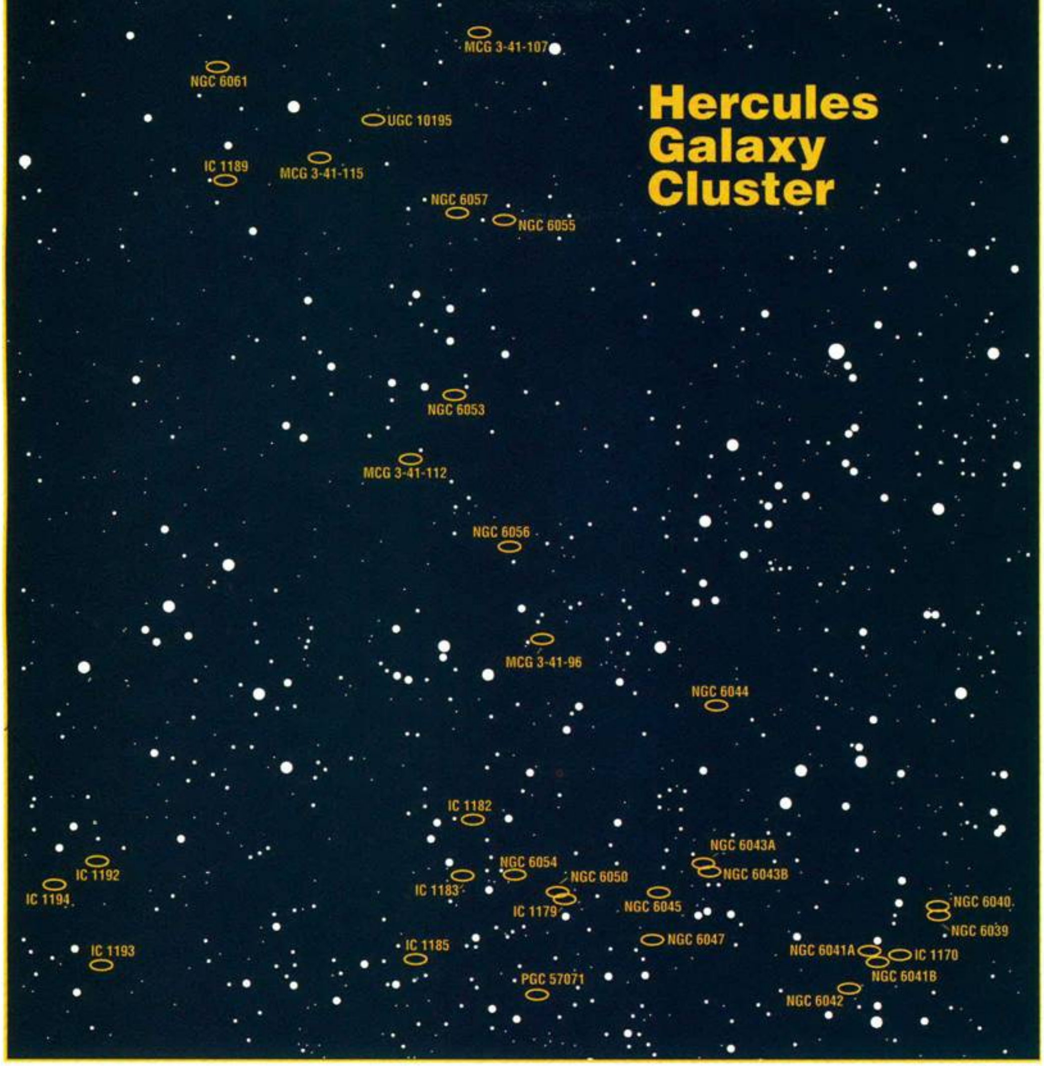
Galaxy	Mag.	Size
NGC 6040	14.6	1.6' by 0.8'
NGC 6039	14.0	—
IC 1170	15.3	—
NGC 6041A	14.3	—
NGC 6041B	14.4	—
NGC 6042	14.9	—
NGC 6043A	15.4	—
NGC 6043B	15.5	—
NGC 6045	14.9	—
NGC 6047	13.6V	1.3' by 1.3'
PGC 57071	15.9	—
NGC 6050	14.9	—
IC 1179	15.6	—
NGC 6054	15.8	—
IC 1183	15.4	—
IC 1182	15.2	—
IC 1185	15.1	0.8' by 0.6'
IC 1178	14.9	—
IC 1181	15.6	—
IC 1193	15.0	—
IC 1194	15.5	—
IC 1192	15.7	—
NGC 6044	15.2	—
MCG 3-41-96	15.9	—
NGC 6056	14.9	—
MCG 3-41-112	15.8	—
NGC 6053	15.5	—
NGC 6055	14.9	1.5' by 1.0'
NGC 6057	15.4	—
MCG 3-41-107	15.6	—
UGC 10195	15.4	—
MCG 3-41-115	15.4	—
IC 1189	15.5	—
NGC 6061	14.5	1.4' by 1.2'

All magnitudes are photographic, unless noted by a subscript V.

I'll bet virtually every galaxy you've ever seen is a neighbor. All spiral galaxies that show detail in large backyard scopes lie closer than 100 million light-years. The Virgo Cluster, the nearest large group of galaxies, sits at a "neighborly" distance of 50 to 75 million light-years (depending on whose research with the Hubble Space Telescope you believe). But a vast universe of galaxies and clusters of galaxies lies beyond this familiar one. And many of the more distant galaxies, though they don't show much detail, lie within reach of large telescopes. The thrill lies in taking a telescopic jump into *real* deep space, hundreds of millions of light-years off away.

The visual "deepness" in deep-sky observing becomes most apparent when you aim your telescope at galaxy clusters. On a crisp, dark night, you may spy a handful or more of galaxies in a single telescopic field. Galaxy clusters also offer a unique perspective on galaxy interactions: the galaxies in them are different than solitary galaxies. Repeated close passages of galaxies to each other can distort or even cause separate galaxies to merge into a single clump of stars, gas, and dust. The cores of galaxy clusters are often rich in elliptical and lenticular galaxies, beneficiaries of these interactions. And the spirals in many clusters appear to have exhausted their supplies of gas, making them appear like lenticulars.

In any case, two great catalogs of galaxy clusters, those by George Abell and Fritz Zwicky, offer many examples of galaxy clusters, some of the brightest of which are summarized in the box below. One of the most beautiful examples of a cluster in the spring sky is the **Hercules Galaxy Cluster** (Abell 2151), a rich collection of several dozen galaxies that lies about 500 million light-years away. This group resides in southern Hercules near the border with Serpens Caput, 1° east of the 5th-magnitude star 5 Herculis (see *Uranometria 2000.0;* vol. 1, chart 155). Seeing half a billion light-


Hercules Galaxy Cluster
MCG 3-41-107
NGC 6061
UGC 10195
IC 1189
MCG 3-41-115
NGC 6057
NGC 6055
NGC 6053
MCG 3-41-112
NGC 6056
MCG 3-41-96
NGC 6044
IC 1182
NGC 6043A
NGC 6043B
IC 1192
IC 1194
NGC 6054
NGC 6050
IC 1183
IC 1179
NGC 6045
NGC 6040
NGC 6039
NGC 6047
IC 1193
IC 1185
NGC 6041A
IC 1170
NGC 6041B
PGC 57071
NGC 6042

Kathy Kolstedt

years is no easy trick, but I've found that on a dark, transparent night I can pick out the brightest galaxies in the Hercules Cluster with a 13-inch Dobsonian working at moderate powers.

The Hercules Cluster is the brightest knot in a giant supercluster of faint galaxies that stretches 25° across the sky. Its most striking feature visually is a high percentage of spiral and irregular galaxies relative to other clusters. A bright east-west arc of galaxies dominates this cluster. The brightest single galaxy is **NGC 6047,** a lenticular measuring 1.3' across and located near the center of the cluster's bright group. Just north of NGC 6047 is the most distinctive object in the Hercules Cluster, **NGC 6045,** a 15th-magnitude edge-on galaxy that appears to have a little "hook" at one end. This is either a small galaxy interacting with NGC 6045 or a chance background alignment.

The core of the group holds other galaxies observable in scopes as small as 13 inches. Among the group's most prominent galaxies are **NGC 6040, NGC 6039, NGC 6041A, NGC 6041B, NGC 6050,** and **IC 1185.** With my 13-inch scope at 195x and 207x, I found most of the brighter galaxies recognizable and thought the cluster was visually impressive. If the sky is less than ideal, however, a 16-inch or 18-inch scope may be required to see some of these objects. The brightest galaxies in the group are surrounded by a faint cloud of PGC galaxies. The accompanying finder chart, based on a photograph made with the 5-meter Hale telescope, labels only those galaxies I observed in the 13-inch scope. Take some time to slowly work your way around this great cloud of distant galaxies — you may be surprised at how many of these little guys you see. ☐

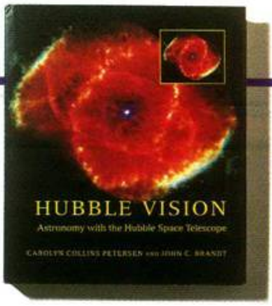
Galaxy Clusters for Large Backyard Scopes

Cluster	Approx. Position (2000.0)	Constellation
Abell 119	1h2m –1°30'	Cetus
Abell 194	1h26m –1°22'	Cetus
Abell 426	3h16m 41°20'	Perseus
Fornax	3h30m –36°00'	Fornax
Cancer	8h18m 21°14'	Cancer
Abell 1367	11h44m 19°59'	Leo
Abell 1656	12h57m 28°14'	Coma Berenices
Centaurus	13h22m –42°45'	Centaurus
Abell 2151	16h5m 17°46'	Hercules
Abell 2199	16h27m 39°38	Hercules

Tom Johnston is an avid deep-sky observer, blessed with a desire for seeing distant galaxies, who lives in Boulder, Colorado. In the past he has written for Deep Sky *magazine.*

A Hubble Double Dip

by Alexandra Witze


HUBBLE VISION
Astronomy with the Hubble Space Telescope
CAROLYN COLLINS PETERSEN AND JOHN C. BRANDT

Hubble Vision: Astronomy with the Hubble Space Telescope
Carolyn Collins Petersen and John C. Brandt, (Cambridge University Press, 1995), ISBN 0-521-49643-8, 252 pages, hardcover, $39.95.

A Journey Through Time: Exploring the Universe with the Hubble Space Telescope
Jay Barbree and Martin Caidin, (Penguin Studio Books, 1995), ISBN 0-670-86018-2, 232 pages, hardcover, $29.95.

Few scientific instruments have endured as much public scrutiny as the Hubble Space Telescope. Ever since the concept of a space telescope was first dreamed of earlier this century, it has suffered a barrage of intense criticism. When Hubble was finally launched in 1990, the outcry only intensified when astronomers learned to their horror that its primary mirror had been ground incorrectly, blurring the telescope's billion-dollar vision.

Now, a pair of beautifully illustrated books aim to explain why Hubble is worth all the effort and cost poured into it. Both *A Journey Through Time* and *Hubble Vision* share an unshakable belief in the value of the space telescope. Yet these books are distinctly different. Each aims for a different audience, and readers may be satisfied with only one or the other.

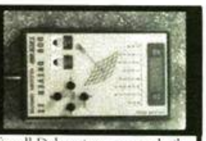
Hubble Vision offers a straightforward explanation of the science coming out of the Hubble observations. If you want to know exactly what results the telescope has been churning out from each corner of the universe, look no further. The chapters here are clearly organized: A brief overview of the telescope's history, from concept to launch to repair mission, is followed by an explanation of Hubble's purpose and function. From there the book discusses Hubble's observations, from near to far. First comes the solar system, then stars and the interstellar medium, followed by galaxies and the ways in which Hubble is attempting to help solve cosmological questions.

Somehow this book has managed to include some of the more recent images coming from the telescope (something that cannot be said for *A Journey Through Time*, which has the same release date). For example, *Hubble Vision* squeezes in the stunning Hubble views of Mars taken during the February 1995 opposition that were featured in the June issue of ASTRONOMY. *A Journey Through Time* relies instead on an old Viking mosaic.

The writing in *Hubble Vision* is straightforward, the descriptions clear. While it does give you the background to appreciate the importance of the scientific results, it lacks a certain vision beyond extolling the virtues of the telescope since its repair. Co-author Brandt is an astronomer with the University of Colorado and a principal investigator for Hubble's high-resolution spectrograph. His expertise shows in the book's solid and unassailable detail. This is a book to refer to frequently, not something to be read under a darkening starlit sky.

On the other hand, *A Journey Through Time*, by two science writers, eloquently and unabashedly celebrates the beauty of astronomy. With chapter titles such as "Magic of the Stellar Kingdom" and "The Wonder of It All," this book leaves no doubt as to its purpose: To convey the awe-invoking beauty of the universe. Unfortunately, it doesn't tell you nearly as much about the space telescope as *Hubble Vision* does.

The first nine chapters of the book contain lovely descriptions of the solar system, from the Sun to the outer reaches of the Kuiper belt. Sur-



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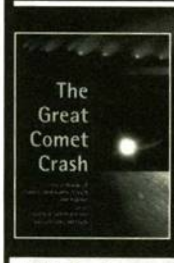

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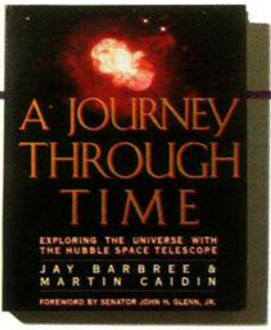
A JOURNEY THROUGH TIME
EXPLORING THE UNIVERSE WITH THE HUBBLE SPACE TELESCOPE
JAY BARBREE & MARTIN CAIDIN
FOREWORD BY SENATOR JOHN H. GLENN, JR.

prisingly, Hubble plays a small role in these chapters. The authors refer to what we can learn about our planetary neighbors from Hubble, but little about what the telescope has already accomplished. For example, the entire chapter on Mars refers to Hubble but a few times, by suggesting how the telescope will help fill the information gap left by American and Russian probes that have already visited the Red Planet. Barbree and Caidin do, however, include a discussion of how Hubble was used to study Comet Shoemaker-Levy 9's collision with Jupiter in July 1994.

The latter part of the book begins to discuss actual scientific results from Hubble. With a chapter also entitled "A Journey Through Time," the authors describe the purpose of the telescope: to peer back through billions of years, to the beginning of the universe and time. They are optimistic that Hubble will accomplish its task. Take, for example, their vision for the telescope's future:

"Before the story of human civilization is over, Hubble will take us back to a universe we cannot recognize. We will drift back to the doorsteps of creation, back to when the beautiful elliptical and spiral galaxies we see today were unwieldy clumps of protostar material, gathering into gravity-rammed spheres so massive they raged through stellar life, devouring their substance in violence that doomed them to premature explosions — stars being born and dying so rapidly they spattered the early universe like some fantasy of celestial fireworks. Out of chaos would come order."

If you like this sort of writing, read *A Journey Through Time*. But if you want to know what hard science the telescope is doing, check out *Hubble Vision* instead. ☐

Alexandra Witze is an associate editor of Earth *magazine.*

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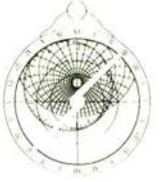

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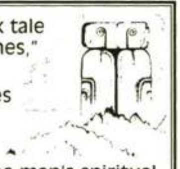

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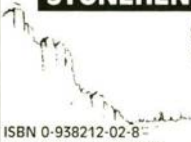

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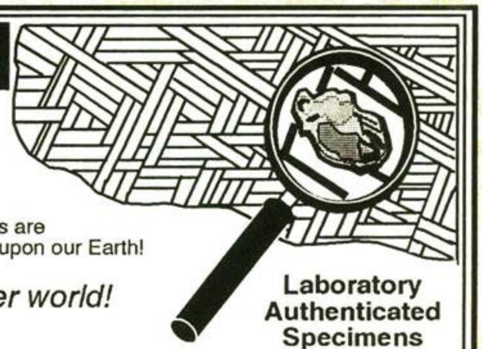

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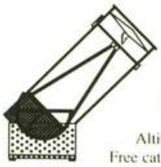

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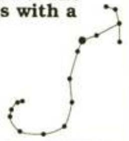

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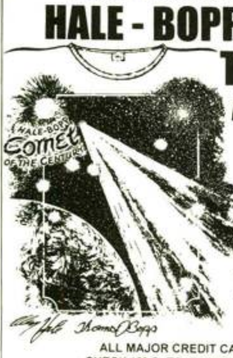

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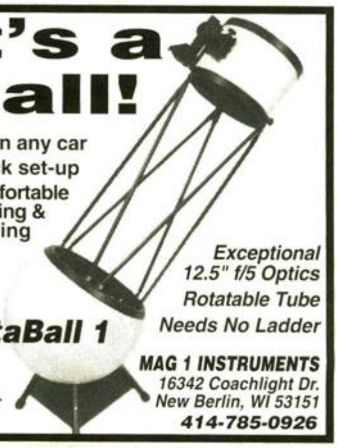

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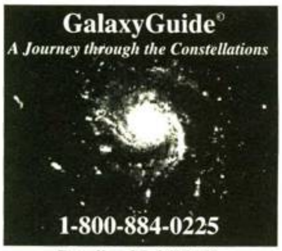

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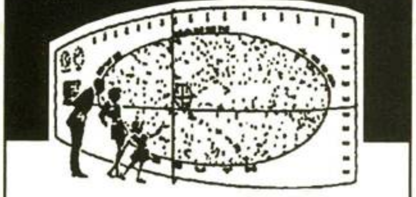

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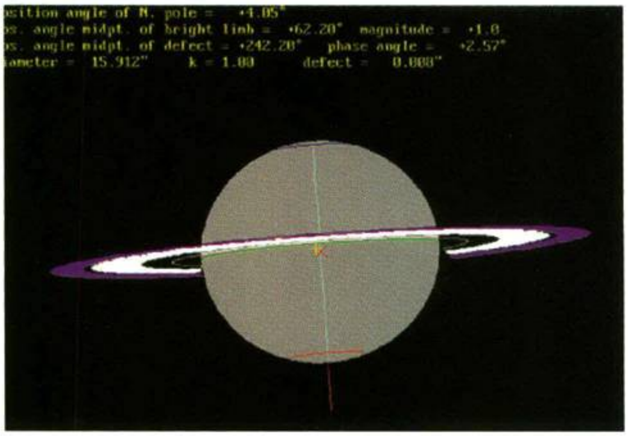
Zephyr Services, 1900 Murray Ave., Pittsburgh, PA 15217, (412) 422-6600, orders call (800) 533-6666, fax (412) 422-9930, e-mail: mail@zephyrs.com. Price: $39.95. Minimum requirements: IBM PC-compatible computer, 640 KB of memory, and color graphics.

Planetary observers — how do you determine the position angle of Saturn's north pole or the phase angle of Mars? You could use the *Astronomical Almanac* and interpolate values, or you use its electronic cousin, *MICA*, which will give you values for any day and time. But neither has a graphical display of the planet and you have to flip between several pages or screens to gather all the information you need.

AstroVizier provides all the information observers need plus a graphical representation of the planet, all in one convenient package. The opening menu permits the user to translate dates between the Gregorian calendar and the Julian calendar (including corrections to dynamical time that yield the Julian ephemeris date), open a previously created file, or choose the solar system body of interest including the planets, Moon, and Sun.

Choosing a solar system body brings up a series of screens asking for the current time (in Universal Time, but the manual explains how to convert local time to UT) and the date. It then provides a display of the planet with the correct phase and the equator and poles marked on the disk. Typing certain numbers into the keyboard displays tables containing physical information about the planet such as its right ascension and declination, ecliptic latitude and longitude, distance from the Sun, distance from Earth, magnitude, phase angle, diameter, position angle of the north pole, subsolar and subearth points, and more. Jupiter, for example, appears flattened and its information table has central meridian longitudes for Systems I through III for tracking different atmospheric features.



```
sition angle of N. pole =   +4.05°
s. angle midpt. of bright limb =  +62.20°  magnitude =  +1.0
s. angle midpt. of defect = +242.20°   phase angle =   +2.57°
ameter =  15.912"     k = 1.00       defect =   0.000"
```

Waid Baker, the creator of *AstroVizier*, estimates that the program is accurate for dates between BC 4000 and 10,000 AD. Light time, the amount of time light takes to travel from the planet to Earth, is included in the calculations the program makes. Users can save screen information as files and reload them for later use into *AstroVizier*, or they can print the screen for use at a telescope.

A comparison of some of the values produced by *AstroVizier* with those in the *Astronomical Almanac* indicates that the program is pretty accurate. Positions vary by less 0.5" or less, central meridian longitudes by 0.5° or less, and magnitudes by 0.2 or less. Other quantities have errors smaller than the ones just quoted. So *AstroVizier* not only provides the kind of information planetary observers need, but it provides reliable numbers as well. — *Dave Bruning*

The Ultimate Einstein
Digital Bauhaus, 24 West 25th St., New York, NY 10010, (212) 989-6252. Price: $49.95. Minimum requirements for PC version: 25 MHz 80486SX-based computer, 8 MB of memory, 1 MB of free space on a hard drive, double-speed CD-ROM drive (MPC-2 compatible), MPC-compatible sound board and speakers or headphones, mouse, SVGA display capable of 256 colors, and Windows 3.1; Macintosh version: 25 MHz 68030-based computer, color monitor, 5 MB of free memory, double-speed CD-ROM drive, System 7.

Trace Einstein's life, scientific career, politics, and philosophy with this CD-ROM multimedia package. It has a searchable library including Ronald W. Clark's *Einstein: The Life and Times*. A simulator enables users to explore the concepts of relativity. An actor portraying Einstein will respond to users' queries using the scientist's own words.

Visions of Mars
Virtual Reality, 2341 Ganador Court, San Luis Obispo, CA 93401, (805) 545-8515, fax (805) 781-2259, or order at (800) 829-8754. Price: $69.95. Multimedia CD-ROM for PCs and Macs.

Visions of Mars is a commemorative CD-ROM conceived by The Planetary Society and produced by Tome-Warner. The disc is an exact duplicate of one sent to Mars aboard the Russian Mars '96 Lander. It contains greetings to future explorers or Mars colonists from famous astronomers, space scientists, and science fiction writers, as well as thousands of pages of fiction about and numerous photos and paintings of the Red Planet. This time capsule of Earth's view of Mars spans four centuries, represents 26 nations, and contains text in 10 alphabets and 17 languages. ☐

Software developers may send new programs and upgrades to AstroBytes, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612 or e-mail bytes@astronomy.com. Check out ASTRONOMY's home page at **http://www.kalmbach.com/astro/astronomy.html.**

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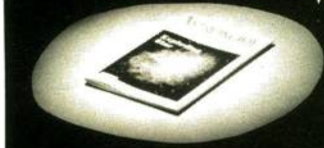

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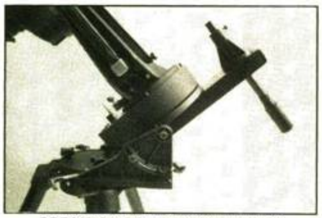

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USE THIS ONE TO SEE M-83

FILTER OF THE MONTH: The LUMICON Deep-Sky Filter will help you see the lovely barred spiral galaxy M-83 in Hydra. Spiral structure should be visible in 13" or larger telescopes in dark skies.

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2" Giant Barlow - 2x	$179
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7mm Nagler, 1¼" eyepiece, 82° field	$219
9mm Nagler, 82° field, 1¼" or 2"	$239
13mm Nagler, 82° field, 1¼" or 2"	$299
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Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the LUMICON Deep-Sky (DS) Filter.

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LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON O-III proved to be our favorite... It gave the greatest contrast gain." ***ASTRONOMY*, February 1991**

AMAZING O-III FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

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Rich Zepernick, Cresskill, NJ

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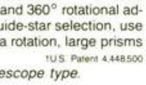

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5. **LUMICON EASY-GUIDER** (selection to left)

6. **LUMICON 48mm DEEP-SKY FILTER $119.50**
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LUMICON Rich-Field Viewer on C-8 with LUMICON 2" star diagonal and 2" eyepiece.

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†Includes 2" enhanced aluminum Star Diagonal (may not reach focus on some telescopes).

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$1495

Meade 8" LX200 Telescopes

LX50 - includes dec. motor, hand controller. **LX200** - full computer control w/64K obj. mem. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your LX200 Schmidt-Cassegrain.

NEW! 8" LX50 w/wedge, tripod, hand controller ($115 P&S)	**$1495**
8" LX200 w/computer ($105 P&S)	**$2495**
Wedge for photographing w/8" LX200 ..	**$139**
7" LX50 f/15 Maksutov w/wedge ($125 P&S)	**$1595**
10" LX50, f/10 w/wedge, tripod, dec. motor, hand controller ($145 P&S)	**$1795**
10" LX200 w/computer ($145 P&S) ...	**$2895**
12" LX200 (f/10 only)($215 P&S)	**$3995**
Super Wedge for photogr. w/10",12" LX200	**$395**
16" LX200 f/10 w/tripod ($385 P&S) .	**$14,950**
Dew Shields: 8" .... **$119;** 10"	**$129**
12" .... **$189;** 16"	**$289**

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4" f/10 w/motor ($40 P&S)	**$699**
Model 2120B 10" w/wedge, tripod .	**$1599**

PHOTOGRAPHY ACCESSORIES

Cassegrain EASY-GUIDER 4", 8", f/6 or f/10	**$249**
Giant EASY-GUIDER for 10"/12" f/4-f/10 .	**$395**

MEADE STARFINDERS

8" f/6
$699*

New 8" f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions. These are complete telescope systems with motor drive & finderscope (equat. only), mount, and 25mm (=48X) eyepiece. New DC motor runs on 4AA batteries.

6" f/8 Dobsonian Starfinder ($46 P&S)	**$325**
6" f/8 Equat. Starfinder 6(add $79 P&S) ...	**$599**
8" f/6 Dobsonian Starfinder (add $59 P&S)	**$425**
8" f/6 Equat. Starfinder 8 (add $89 P&S) ..	**$699**
10" f/4.5 Dobsonian Starfinder ($85 P&S) ..	**$595**
10" f/4.5 Equat. Starfinder 10 (add $99 P&S)	**$799**
12.5" f/4.8 Dobsonian Starfinder ($95 P&S)	**$795**
16" f/4.5 Dobsonian Starfinder (freight COD)	**$1095**
16" f/4.5 Starfinder 16 (ship. freight COD) .	**$2495**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $50-$100 higher.

ACCESSORIES

LUMICON carries all Meade accessories.

LUMICON Single axis drive corrector .	**$99**
Magellan computer; specify Dob. or Eq. ($15 ship)	**$295**
Meade 47M Dual-axis drive corrector with tangent arm & electric declination ..	**$475**

SKY VECTOR™ $249!!

Includes Computer, Encoder, Hardware

LUMICON ACCESSORIES

LUMICON. Livermore. CA 94550 (510) 447-9570 FAX (510) 447-9589

LOW PRICE—from $249

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $249

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $289

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ $389

IMPROVED!—5500 Additions / Corrections

NGC-Sky Vector™
OFF ON
DIM
MODE
ENTER
UP
DOWN
LUMICON®

Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth, Meade 6-16" Dobsonian.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2" EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8".

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER .	**$189.50**
2" EASY-GUIDER (Mamiya 645)	**$239.50**
2" Adapter for Pentax 6X7 ...	**$129.00**
2" Adapter for Hasselblad .	**$229.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing ...	**$26.00**

2" DELUXE BARLOW

1.8x Multiplier Lens (2" Barlow)

LUMICON 1.8x Multiplier Lens (2" Barlow) **$259.00**

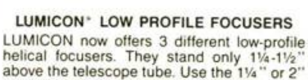
LARGE UV/DUST SEAL

Protect the optics of your 8-14" Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080 ...	**$119.50**
UV/Dust Deal for Celestron C-8 ...	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14 .	**$89.50**

LOW PROFILE FOCUSERS
New! Thread-on for Odyssey

FROM $69.50



LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$69.50**
LUMICON 2" Helical Focuser 1½" high	**$75.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2" Astro Systems focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$189.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$69.50**, right-angle	**$69.50**
1¼" straight-thru 80mm SUPER-FINDER .	**$189.50**
1¼" right-angle 80mm SUPER-FINDER ..	**$199.50**
1¼" right-angle version, w/star diagonal ..	**$239.50**
25mm Cross-hair 1¼" eyepiece (12X)	**$49.00**
Large mounting rings for 80mm Finder	**$55.00**
1¼" Star Diagonal **$49**, Mounting Brackets.	**$39.50**
1¼" 45° diagonal for correct left-right views	**$59.50**

LOTS OF ADAPTERS

2" adapter for C-8, Meade 2080, etc. ..	**$29.50**
2" adapter for C-80, C-100 refractor ...	**$39.50**
2" adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2" adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1" long 1¼" OD thread-in extension ...	**12.00**
2½" long extension (holds 1¼" filters) .	**19.50**
4½" long extension for 1¼" eyepieces	**$25.00**
3" long extension for 2" eyepieces* ..	**$29.00**
2" long extension for 2" eyepieces* ..	**$29.00**

VIEWING ADAPTERS

2"/1¼" reducing bushing,threaded 48mm*	**$25.00**
2"/T-thread adapter, threaded 48mm* ..	**$25.00**
T-thread/1¼" adapter	**$25.00**
F/10 2" or 1¼" eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2" Diagonal/Giant Easy-Guider	**$39.50**

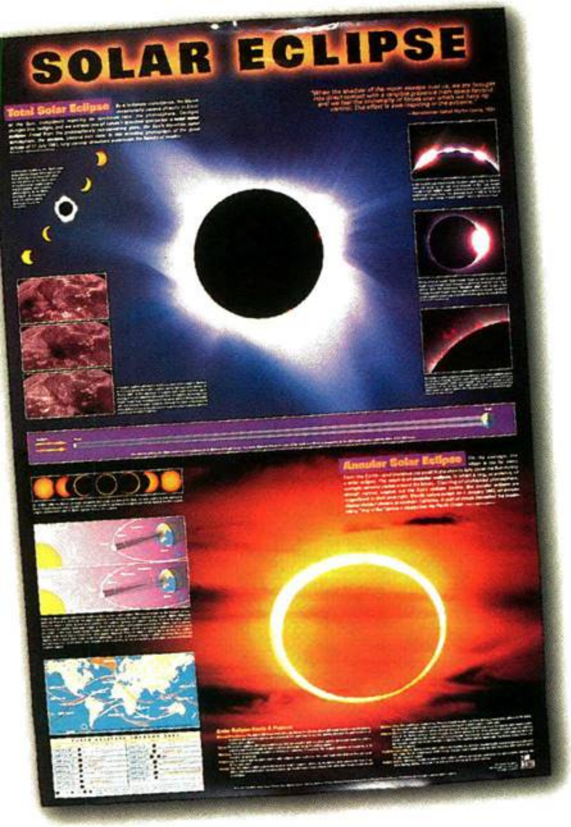
**Threaded to hold 48mm filters.*

NEW PRODUCTS

Solar Eclipse Poster

From MindMatter Publishing comes this colorful 24" x 36" poster that uses photography and diagrams to explain the nature of solar eclipses. Photos convey each stage of a solar eclipse and feature close-ups of spectacular details visible during totality. A series of satellite photos show the Moon's shadow moving across Earth during the July 1991 solar eclipse. A drawing done to scale explains how the Moon casts its shadow upon Earth. Another side box demonstrates how circumstances differ between total and annular solar eclipses. A map and table lay out when and where solar eclipses occur through the year 2008. The poster ships rolled in a mailing tube.

MindMatter Publishing, P.O. Box 1599, Soquel, CA 95073-1599; (408) 479-7359; fax: (408) 479-7180; e-mail: 74462.2452@compuserve.com. Solar Eclipse poster: $9.95, plus $3 shipping and handling (California residents add 7.25% sales tax). Visa and MasterCard accepted; dealer inquiries welcome.

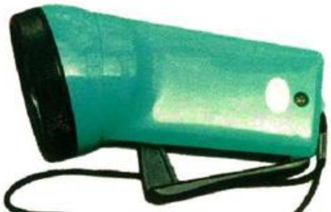


Economically Priced Binoculars

Celestron's Enduro line of center-focus binoculars, all priced under $100, features fully coated optics and come with a rubber covering for greater durability. The 7x35 binoculars offer a 9.2° field of view with an eye relief of 11mm and weighs 22 ounces. The 8x40 has an 8.2° field of view, a 12mm eye relief, and weighs 25 ounces. The 7x50 and 10x50 afford 6.8° and 7.0° fields of view, respectively; both provide a 13mm eye relief and weigh 28 ounces. All binoculars come with a soft case for storage and a limited lifetime warranty.

Celestron International, 2835 Columbia Street, Torrance, CA 90503; (310) 328-9560; fax: (310) 212-5835. Celestron Enduro Binoculars, 7x35 (model 71180): $86; 8x40 (model 71181): $88; 7x50 (model 71182): $90; 10x50 (model 71183): $92.

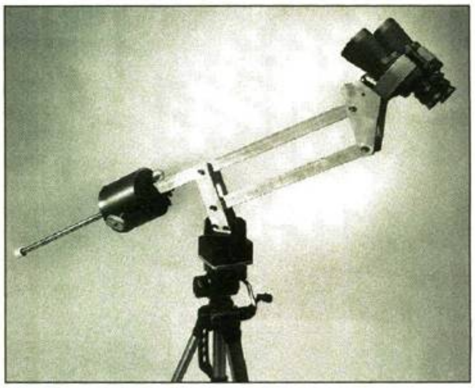
Batteryless Red Flashlight



The ForeverFlash red LED flashlight uses the piezoelectric principle to provide light without the use of batteries. A squeezable switch varies the LED's light output: Squeeze harder and the diode puts out more light. Manufacturer TW Engineering estimates the red light should last more than a decade. The light's solid, waterproof nylon housing measures 5.3" x 2.5" x 2.8" and weighs 4 ½ ounces. It comes with a one year warranty.

TW Engineering, 2970 Orange Avenue, Suite 55, Anaheim, CA 92804, (714) 527-2547 (voice and fax). The TP9501 ForeverFlash: $30.

Binocular Mount



Two models of the Virgo T&T Bino-mount fit on any video or photo tripod to steady most binoculars on the market for astronomical viewing. Its "flexible parallelogram" design lets an observer adjust binocular height without losing an object in view. Bino-mount uses Velcro straps to secure binoculars in a padded cradle. A screw in the cradle accepts oversized binoculars with built-in L-shaped attach brackets. The polished aluminum mount moves freely in altitude and azimuth. Altitude motion locks with a side-mounted thumb screw. Azimuth rides on a 3.5-inch square base for smoother panning. An adjustable counterweight slides along a bar assembly to accommodate a variety of binocular designs. This counterweight constitutes a majority of the mount's 7.5-pound total weight.

Virgo Astronomics, 608 Falconbridge Dr., Suite 46, Joppa, MD 21085; (410) 679-7055; fax: (410) 679-2376. Virgo T&T Bino-mount, 20" model for binoculars up to 70mm: $109.95; 25" model for up to 100mm binoculars: $119.95.

Cordless and Computerized Equatorial Mount

Meade Instruments' line of 6-, 8-, 10-, and 16-inch Starfinder equatorial reflectors now track the sky using DC power from four AA-sized batteries tucked into a trap door in the drive corrector. An internal switch in the redesigned mount also permits the scope to track in the Northern or Southern Hemisphere. The redesigned mount is optimized to work with the new Magellan I and II computerized mount systems. This system has a 12,218-object database that includes the positions of more than 12,000 NGC and Index Catalog objects, 100 Messier objects, and all eight planets. The readout on a hand-held paddle guides the observer while he or she manually slews the telescope. Magellan II (pictured) allows for electronic, dual-axis sluing at speeds of 2, 8, 16, or 32 times the mount's normal drive rate.

Meade Instruments Corporation, 16542 Millikan Avenue, Irvine, CA 92714-5032; (714) 756-2291; fax: (714) 756-1450. DC-powered Starfinder Equatorial Reflectors: 6" f/8: $599.95; 8" f/6: 699.95; 10" f/4.5: $799.95; 16" f/4.5: $2495. Magellan I computerized mount system for Starfinder equatorial mounts: $295. Magellan II for 6", 8", and 10" Starfinder equatorials: $495; 16": $595. Prices for packing and shipping are extra.

Meade & More!

Meade Telescopes In Stock!
- LX50 and LX200 *8-inch, 10-inch, & 12-inch*
- 7-Inch Maksutov's *LX50 or LX200 Mount*
- Starfinder Equatorials *Now with DC Drive!*
- Starfinder Dobsonians *6", 8", 10", 12.5"*
- 60 and 90mm Refractors *Alt-Az & EQ.*

Shutan Stocks Almost Every Meade Telescope!

Meade Pictor 416 CCD Special— Get $800 in FREE Accy's!
See Meade ad or call for details on this fantastic offer!

NEW!

Meade Series 3000 Plossl Sale:
5, 6.7, 9.5, 16, or 25mm
- Made in **Japan!**
- Multi-coated
- 4-element!

Priced Right!
SALE $49 ea.
40mm S3000 Plossl in stock for only $80

Meade Barlows:	
#122 2x 1.25"	$48
#127 2-3x 1.25"	60
#140 2x 1.25"	80
2045D Accy's:	
Barlow 126 2x	48
Car cord	20
Carrying case	80
Tripod & wedge	275
Starfinder Accy's:	
Dust caps	call
Dec 55	78
Drive 43 110v-12v	129
Drive 47M (6-8-10)	429
Magellan	call

Meade Accy's:	
Accy case 50	$67
Car cord LX200	85
Diagonal 1.25"	42
Diagonal .96-1.25"	28
Diagonal .96" 45°	53
Diagonal 1.25" 45°	53
Diagonal 929 2"	100
Epoch2000	call
EP holder 1.25"	25
Focuser 70 1.25"	49
Focuser 680 2"	100
Focuser 682 2"	100
Finder 8x50	70
Finder 634-6x30	50

Meade Accy's:	
Filter set of 4	$60
Filter ND96 1.25"	20
Illum 12mm w/cord	80
Illum 12mm-wless	100
Illum 9mm w/cord	130
Illum 9mm-wless	150
Lenshood 8"	114
Lenshood 10"	124
Lenshood 12"	174
Magellan	call
Nebula 908B	80
Nebula 908N	90
Nebula 911B	100
Nebula 911N	120

Meade Accy's:	
Off-axis guider	$80
Piggy brkt 8/10"	32
Piggy brkt 12"	49
Reducer f:6.3	130
Skylight/seal	48
Tele extender	30
Tele ext-variable	40
T-adapt: vari-proj	40
Vari pol 905	50
Weight set 8"	85
Weight set 10"	90
Weight set 12"	100
Wedge 8"	134
Wedge 10" Super	395

Meade Series 4000	
Super Plossl 6.4, 9.7, 12.4, 15, 20, 26	$88
32 or 40mm	110
56mm	230
Super Wide 13.8	160
Super Wide 18	170
Super Wide 24.5	199
Super Wide 32	280
Super Wide 40	340
Ultra Wide 4.7	180
Ultra Wide 6.7	220
Ultra Wide 8.8	270
Ultra Wide 14	330

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We carry over 40 titles of Astronomy books! Call today for immediate delivery!

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Zero-Image-Shift Focusers!

NGF-S (SCT)	$249
NGF-S Mini	199
NGF-3 Mini	94
NGF-3 Mini motor	179

LX200 Keypad Holder
$34

Leveling Wheels!
Meade 8"/10" SCT, 4"/5" APO, Starfinder 6"/8"/10"
only $144
For Meade 12" SCT and 6"/7" ED APO ***$189***

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In Stock $42

TeleVue

Genesis SDF	Call
Pronto	Call
Renaissance	Call
Panoramic mt	349
Gibraltar mt	449
Starbeam-T	179
Cam. adapter	39
Piggycam	45
Eyepiece proj	69

Ext tube	$33
Bino Viewer	call
Polar finder	119
Nagler:	
4.8mm New!	168
7mm New!	216
9mm	234
12mm Type2	275
13mm	299
16mm Type2	299
20mm Type2	368

Plossl:	
New 8, 11, 15, 20, 25mm	call
7.4, 10.5, or 13	70
17, 21, or 26	70
32 or 40mm	109
55mm	224
Wide Field:	
15 or 19mm	136
Paracorr	call

Panoptic:	
15mm	$204
22mm	269
27mm	319
35mm	354
Barlow interface	94
Barlows:	
2n New!	104
3x New!	104
Big Barlow 2"	162

Sale!
Foam Lined Accessory Case!
$50

Celestron

C5+ w/wedge	Call
Celestar-8	Call
C5 tripod	Call
C5 fitted case	179
C5 lenshood	49
Dew shield-8"	29
F:6.3 reducer	127
MFFT-55	159
Ultima 2x 1.25"	75

Kendrick

12v Controller	$65
1.25"/2" heater	35
7"/8" heater	50
9"/10"/11" heater	60
12" heater	70
8" dew shield	45
10" dew shield	60
12" dew shield	80

Call for other sizes!

1000 Oaks Solar Filters

4" full-aperture	$ 60
8" full-aperture	109
10" full-aperture	119
12" full-aperture	139

Other sizes in stock!
Precision polished glass, triple-coated in machined aluminum cell. Image is yellow-orange— no need for secondary filtering!

Konica
ASA 3200 Color Print
3-24 exp. rolls $21

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PRECISION SOLAR FILTERS

NEW SOLAR VIEW™

Manufactured exclusively for Solar View by Thousand Oaks Optical.

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- **Sizes to fit all telescopes and binoculars**
- **6 year warranty**
- **17 years of quality manufacturing in solar filters**
- **Most popular sizes in stock for immediate delivery**
- **30 day unconditional money-back guarantee**
- **10 free solar eclipse viewers with purchase of any filter ($15 value)**

Thousand Oaks Optical solar filters are recognized around the world for their quality, consistent density and even coating across the entire aperture. Thousand Oaks Optical specializes in solar filters only and is the largest solar filter manufacturer. Tens of thousands of their filters are in use around the world. The preferred choice of telescope dealers and used exclusively by NASA aboard the Space Shuttle. Other professional users include: ABC, CBS, NBC & CNN News, NOVA, Discovery, National Geographic and most major universities and observatories throughout the world.

GLASS — Type A (Blue Label)
Same as Type B, except stainless steel is combined in the coating to provide an even more durable surface that highly resists wear due to excessive handling and ultraviolet radiation. Solar image is also yellow-orange.

GLASS — Type B (Silver Label)
Made from high quality hand select glass, machine polished and TRIPLE COATED with our exclusive combination of metal alloys and state of the art equipment. Mounted in a machined aluminum cell ready to attach to telescope. Solar image is yellow-orange. No secondary filtering is necessary. Transmission is 1/1000th of 1% (ND-5)

Type A & B are for unlimited visual use and general photographic use. Instructions, including tips on solar photography are included with all filters.

GLASS — Type C (Red Label)
Coated to a neutral density of 4 for maintaining fast shutter speeds when using slow films. Solar image and optical quality same as Type A & Type B. Type C filters are for photographic use only. Transmission is 1/100th of 1%.

APERTURE	GLASS A	GLASS B	GLASS C
2.4"	52.00	38.00	69.00
3.1"	55.00	42.00	74.00
3.5"-4.5"	65.00	49.00	95.00
5.0"	85.00	62.00	109.00
6.0"-7.0"	92.00	67.00	119.00
8.0"-10.0"	112.00	92.00	139.00
11"	139.00	99.00	159.00
12"-13.1"	159.00	119.00	179.00
14"	179.00	139.00	199.00
BINOCULARS			
40-80MM	99.00	79.00	n/a

Unmounted filters for custom applications are $14.00 less than prices listed above.

PRICE GUARANTEE: If you find a lower price on any competitive brand of glass solar filter, simply note the brand and we'll automatically match it.

ORDERING INFORMATION
Solar View filters are shipped free in continental U.S. Please specify telescope brand and/or outside diameter measurement of telescope tube.

DEALER INQUIRIES INVITED

Tele Vue "WHEN YOU WANT THE FINEST"

We stock the entire Tele Vue line for immediate shipment. - All items also on display and available for purchase and pick up at our showroom.

Mid-Winter Sale Prices Now in Effect
Contact us: The Tele Vue Specialists

Imagine a Walk in Space!

NAGLERS 82° Apparent Field of View
Patented Tele Vue Naglers offer the widest, sharpest views available. Why settle for a back seat view when you can experience a *spacewalk?*
Choose from 4.8, 7, 9, 12, 13, 16 and the amazing 20mm!
Call us today for sharp prices and large selection!

Tack Sharp!

PANOPTICS 68° Apparent Field of View
Attack your sharpness problems with Tele Vue's newest eyepiece — the Panoptics. The 2" 35mm and 27mm are considered to be the sharpest in their focal length class. The 1¼" 22mm and 15mm offer outstanding performance, lighter weight, smaller size and lower cost when compared with similar focal length Naglers.

Tele Vue's Best Eyepiece Value!

PLOSSLS 50° Apparent Fiel
Patented Tele Vue Plo end toward higher-qualit ıs. And today, despite tl ver the sharpest Plossls is the smart way Our stock selection includes 1 , 17, 21, 26, 32, 40 fl. And don't forget the 2" 55m yields the widest true FOV available.

JUST ARRIVED! NEW FOR 1996
Tele Vue Series Plossls
25MM, 20MM, 15MM,
11MM, 8MM

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Exciting Sale Priced Packages for Genesis and Gibraltar — contact us for exciting details which include Free Eyepieces, Solar Filter and More!!

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70MM AP.F6.8, 480MM F.L. Available in 1¼" Image Erect, 1¼" Star Diagonal and 2" Star Diagonal models.
"The little scope — that could"

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GENESIS SDF — FREE Eyepiece
When you purchase this
World Famous Telescope

NEW — 1.25 2x & 3x Barlows

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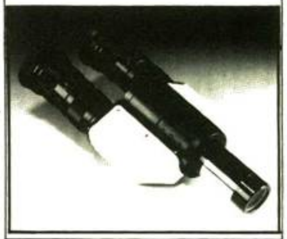
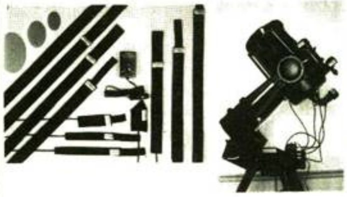
TeleVue Bino Vue Has Arrived!!
Contact Us For Details!!!





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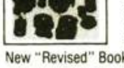

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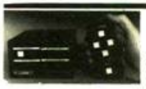

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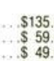

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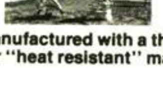

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RESOURCES & PHOTOFACTS

New Planets (page 50)

Internet users can access this home page set up by the University of California at Berkeley http://pio06.urel.berkeley.edu/documentation/Marcy2.htmll. It contains the latest information released from the university's public relations office.

An April Shower (page 72)

Meteor Showers: A Descriptive Catalog, by Gary W. Kronk (Enslow Publishers, 1988). Provides detailed information on several dozen meteor showers visible each year.

Hypercharge Film (page 78)

A Manual of Advanced Celestial Photography, by Brad Wallis and Robert Provin, (Cambridge University Press, 1988). An excellent overview of advanced astrophotography techniques, including gas hypering.

Exotic Eclipse (page 74)

Chasing the Shadow, by Joel Harris and Rich Talcott. (Kalmbach Books, 1994). A complete guide to eclipse observing. Projects solar eclipses through the year 2020. ☐

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p. 54: John Shibley, 200mm lens at f/4.5, ISO 400 film, 5-second exposure on April 2, 1984; **p. 59:** Kirk Wines, 50mm lens at f/16, Kodacolor Gold 100 film, 1/20-second exposures at 9-minute intervals on December 9, 1992; **p. 62:** Jack Newton, 16-inch f/5 reflector; **p. 70:** George Zay, 28mm lens at f/2.8, T-Max 400 film, 26-minute exposure on April 23, 1994; **p. 78:** Michael Stecker, North America and Pelican Nebulae in Cygnus, 5-inch f/6 Astro-physics refractor telecompressed to f/4.5, two 60-minute exposures on hypered Fujicolor HG400 film sandwiched and processed with Adobe Photoshop 2.5 software; **p. 80, top:** Jack Marling, North America Nebula in Cygnus, 5½-inch f/1.65 Schmidt camera, 15 minutes through a Wratten #29 filter, unhypered Tech Pan 2415 film; **bottom:** Jack Marling, North America Nebula in Cygnus, 5 ½-inch f/1.65 Schmidt camera, 15 minutes through a Wratten #29 filter, hypered Tech Pan 2415 film.

MEETINGS & EVENTS

April 11
Astronomy Day, Newark, New Jersey. Sponsored by The Newark Museum. Contact Kevin Conod, Dreyfuss Planetarium, Newark Museum, University Heights, P.O. Box 540, Newark, NJ 07101-0540.

April 13
Virginia Association of Astronomical Societies Convention, Chesapeake, Virginia. Hosted by the Back Bay Amateur Astronomers. Contact Robert J. Hitt, Chesapeake Planetarium, 300 Cedar Road, Chesapeake, VA 23320, (804) 547-0153.

April 14
Northeast Astronomy Forum and Telescope Show, Suffern, New York. Sponsored by the Rockland Astronomy Club. Contact Don Urban, 73 Haring Street, Closter, NJ 07624-1709, (201) 768-6575.

April 18-21
Peach State Star Gaze, Jackson, Georgia. Contact Ken Poshedly, Atlanta Astronomy Club, 3440 Everson Bay Court, Snellville, GA 30278, (770) 979-9842, 102745.313@compuserve.com.

April 20
Astronomy Day, Salem, North Andover, and Topsfield, Massachusetts. Sponsored by the North Shore Amateur Astronomy Club. Contact (508) 922-0489.

April 19-21
Astronomy Workshop, Topeka, Kansas. Cosponsored by B.C. Co. and NEKKAL. Contact B. Culbertson, P.O. Box 149, Harveyville, KS 66431.

April 19-21
Delmarva Star Gaze II, Killens Pond State Park, south of Dover, Delaware. Sponsored by the Delmarva Star Gazers Amateur Astronomy Club. Contact Lyle Jones, 230 N. Bradford Street, Dover, DE 19901, (302) 736-9842.

April 19-21
Southern Star, Wild Acres, North Carolina Mountains. Sponsored by the Charlotte Amateur Astronomers

Club. Contact Todd Heavner, P.O. Box 1959, Davidson, NC 28036 or CE@interserv.com.

April 22
Astronomy Day, Pensacola, Florida. Sponsored by Escambia Amateur Astronomers' Assocation. Contact Wayne Wooten, (904) 477-8859.

April 26-27
NIAGfest, North Webster, Indiana. Cosponsored by the Northern Indiana Astronomical Groups and the Great Lakes Region of the Astronomical League. Contact Kurt Eberhardt, 3370 E. Kenway Drive, Warsaw, IN 46580, (219) 269-6289.

May 4
STARCONN 96, Middletown, Connecticut. Contact The Astronomical Society of Greater Hartford, P.O. BOX 2271, Hartford, CT 06145-2271, (860) 871-1277.

May 17-18
Public Star Party, Lemon Lake County Park, Indiana. Sponsored by the Calumet Astronomical Society. Contact Craig Woodley, P.O Box 851, Griffith, IN 46319, (219) 836-4225.

May 22-24
I.A.P.P.P. Big Bear Symposium, San Bernadino, California. Sponsored by the Intermational Amateur Professional Photoelectric Photometry. Contact Lee Snyder, P.O. Box 3964, Incline Village, NV 89450, (702) 831-1931, snyder@rigel.physics.unr.edu.

May 24-27
Riverside Telescope Makers Conference, Camp Oaks, California. Sponsored by the Riverside Telescope Makers Confernce. Contact RTMC, Fox Stephens, 9045 Haven Avenue, Suite 109, Rancho Cucamonga, CA 91730, (909) 948-2205.

July 29-August 17
Youth Camp, Coucouron, France.Sponsored by the International Astronomical Youth Camp. Open to youths ages 16-24. Contact Gwendolyn Meeus, Schapenstraat 11, 3000 Leuven, Belgium. □

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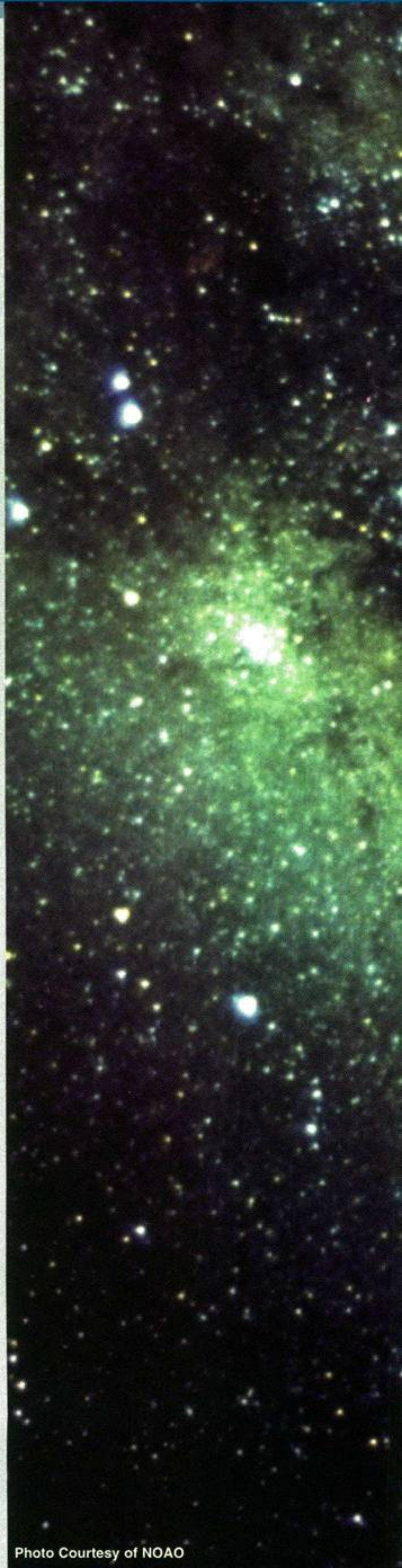

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Adirondack Video Astronomy 86
Adorama 48,49
Analytical Scientific 101
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Astro Physics 86
Astronomics 23,111
Astronomy Shoppe 100,111
AstroSystems, Inc. 88
Augen Optics 86
Ball Photo Supply 100
Bergen County Camera 111
Berger Brothers 100
Bethany Sciences 86
Black Forest Observatory 98
Brazen Sky Productions 86
Blue Sky Pages 100,101
Cambridge University Press 84
Camera Bug 100
Capellasoft 98
Captain's Nautical Supplies 111
CC Sales/Camera Corner 111
Celestron International 16,17,114
Central Camera Co. 89
Cook, Howard 86
Dallas Remote Systems 88
Dover Photo Supply 111
Eagle Optics 101
Earth Flag 87
Ed Hamilton, Bookseller 87
Edmund Scientific Company 18
El Valle Astronomers 88
FC Meichsner Company 111
Focus Camera 25
Fujinon 91
Gayety Travel 86
Helmer Publishing 86
Innovations In Travel 88
International Optics Ltd. 89
Into The Wind 87
Janus 86
JMB Inc 20
K.C. Woodsmith 88
Kalmbach Publishing 21,102
Killgore Southwest 86
Knollwood Books 89
L & T Instruments 101
Learning Technologies Inc. 86
Lumicon 92,93
MagOne Instrument 88
Makewood Products 87
Nick Marella 88
Marketplace, The 86,87,88,89
Meade Instruments 2,3,7,8,9,10,11,12,13
Media Intellect 88
Mountain Skies Astronomical Society 89
Murnaghan Instruments 98
New England Meteoritical Services 87
New Mexico Astronomical 100
Newbridge Communications 19
Northstar Systems 89
Nurnberg Scientific 100
Obsession Telescopes 89
Oceanside Photo & Telescope 111
Optical Guidance Systems 100
Orion Telescope Center 31,32,33
Paradon Industries 15
Parallax Vision Inc 88
Photo Researcher 87
Pocono Mountain Optics 96,97,111
Quadrant Engineering Inc. 85
Rivers Camera Shop 100
Robert A. Haag-Meteorites 89
Santa Barbara Instrument Group 27
Sarasota Camera Exchange Inc 100
Science Connection, Inc 89
Scope City 29,111
Shutan Camera & Video 95
Sky Watchers Inn 88
Software Systems Company 21
Star Gazer Instruments 101
Starry Messenger 87
Starsplitter Telescopes 89
Swift Instruments, Inc. 29
Tech 2000 84
Technical Innovations 20
Tele Vue Dealer Page 111
Tele Vue Optics, Inc 112,113
Roger W. Tuthill, Inc. 91
Vista Instrument Co. 14
Wholesale Optics (Pauli's) 103

READER REPORTS

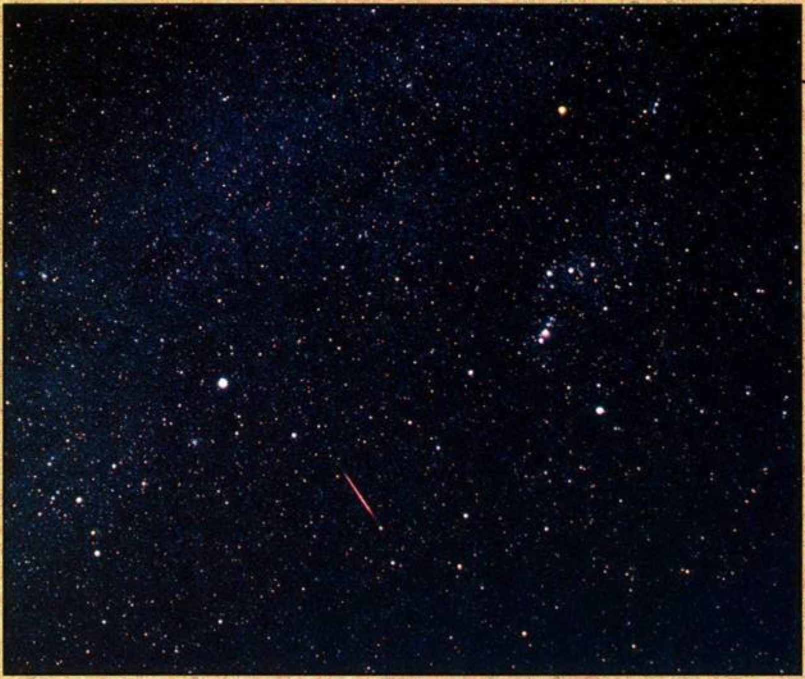
Night of the Leonids

"It was a beautiful night, perfectly clear and a little warm," says Frank Zullo of the evening of the Leonid meteor shower. The Mesa, Arizona, observer set up three cameras in anticipation of catching some Leonids on November 17/18, 1995.

"During the early part of my watch I saw some bright meteors toward the south, specifically near Canis Major," says Zullo. "The crescent Moon rose at 2:45 a.m., and because it was 23 percent illuminated, it didn't affect the viewing much. I captured my best Leonid as it skimmed Canis Major heading toward Delta Leporis (see photo at right)."

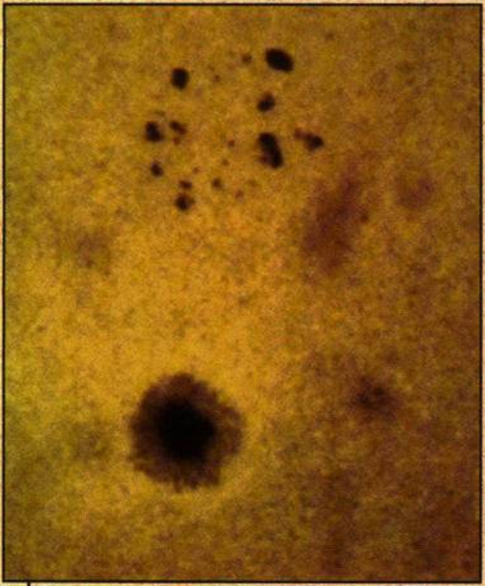
After a break, Zullo prepared to photograph an overhead passage of Mir and the space shuttle. That's when his eye caught something flash. "I turned just in time to see a very bright fireball high in the southeast and watched in amazement as the meteor's path glowed in the form of a persistent train," he says. It was quite a night with Leonids, a fireball, and manmade satellites orbiting overhead — all seen from a dark desert sky.

Venus Orbits the Sun. Mary Dombrowski of Glastonbury, Connecticut, observed Venus once every two weeks for her eighth-grade science project at Gideon Welles High School. She checked the coordinates of the Sun and



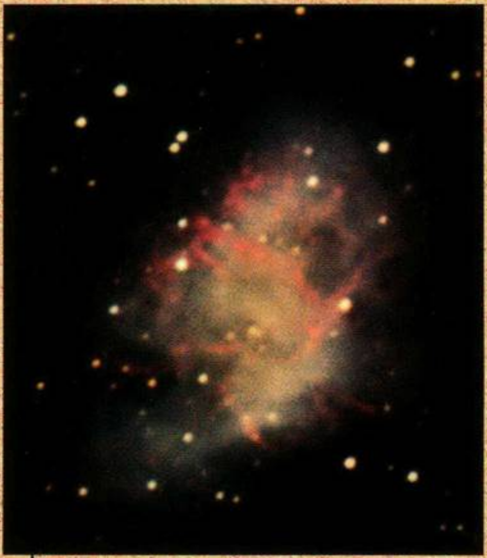
A Leonid Meteor Passes by Canis Major

by Frank Zullo (28mm lens at f/4, Fujichrome 1600 film, 12-minute exposure on November 17/18, 1995)



A Large Multiple Sunspot Group

by Donald F. Trombino and Jeffrey Pettitt (6-inch refractor, taken October 14, 1995)



The Crab Nebula

by Jason Ware (16-inch reflector, Fuji G 800 film, composite of two 45-minute exposures)

Venus from her father's observatory, sketching the planet and recording orbital data. Using an 11-inch SCT, she followed Venus from November 14, 1994, to April 15, 1995, nearly a full orbit.

"An interesting discovery I made is how I think geocentrically," she says. "Venus' orbit lasts 225 days. Compared with Earth's orbit around the Sun, Venus takes much longer to get to the same apparent position." The most valuable things Dombrowski learned, she says, were how to use a telescope and to enjoy seeing the sky.

Geminid Meteor Results. The Geminid meteor shower put on a good show in December, reaching a peak on the 13th and 14th. George Zay of La Mesa, California, observed it on December 14/15 and spotted 110 meteors, 94 of which were Geminids. The brightest shone at magnitude –5 with most producing brief trains.

Sunspots Prove Solar Rotation. Ten-year-old Ryan Propper of Littleton, Colorado, got an observing thrill by plotting sunspots (careful, parents!). With a 2.4-inch refractor, he projected the Sun's image onto a 3x5 card and noted the positions of the sunspots each day. Watching their motion across the Sun's disk showed its rotation. □

ASTRONOMY wants to hear about your observations. Send reports, sketches, photographs, and disks to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612. Please label each photo with name, address, and social security number. You may send written reports and images via the Internet to: rreports@astronomy.com

Emission Nebulae IC 405 and IC 410

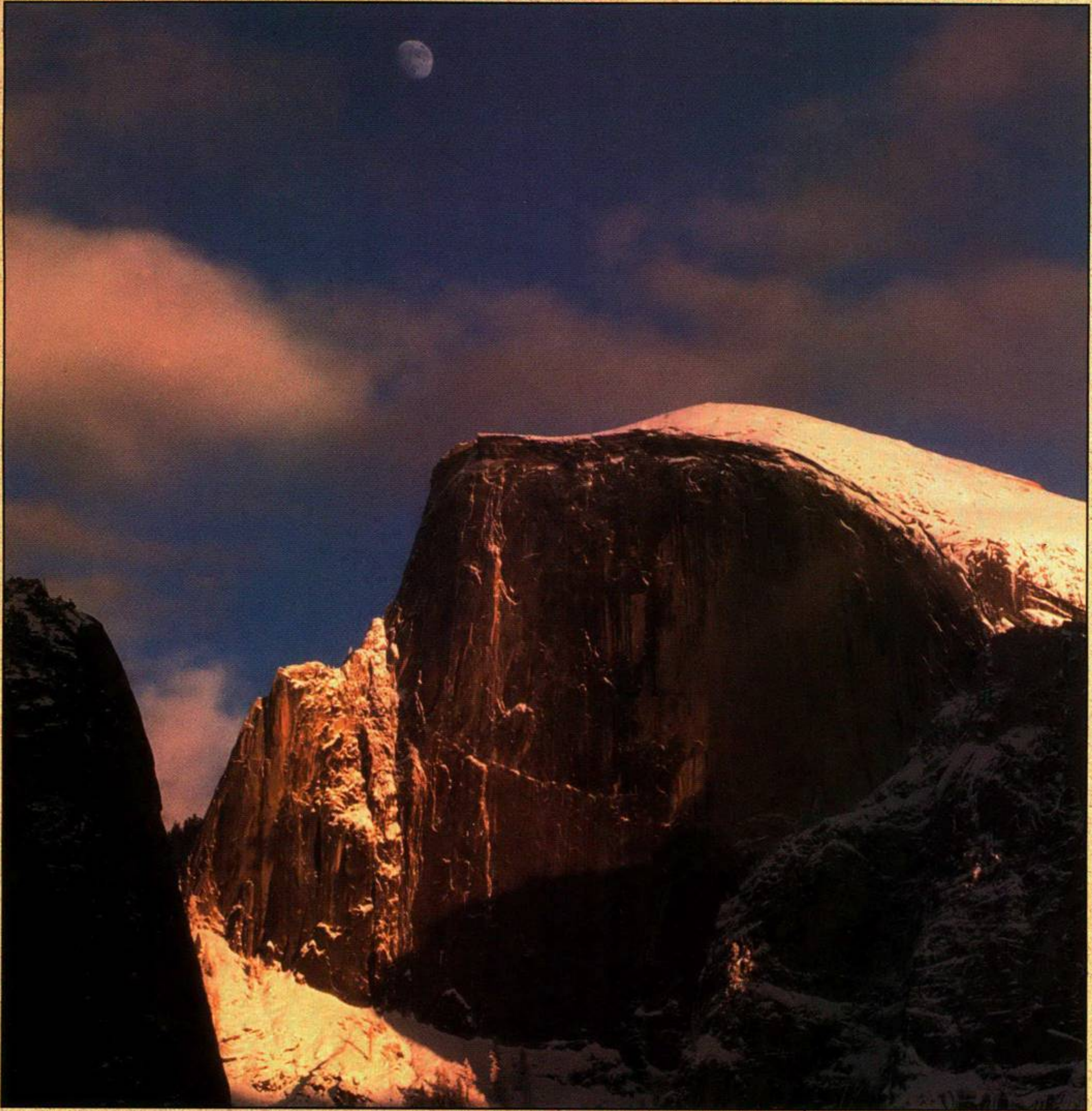
by Michael Stecker (5-inch refractor at f/4.5, hypersensitized Fujicolor HG 400 film, composite of two 60-minute exposures)

Planetary Nebula NGC 6781

by Dale Mais (14-inch SCT at f/7, ST-7 CCD camera)

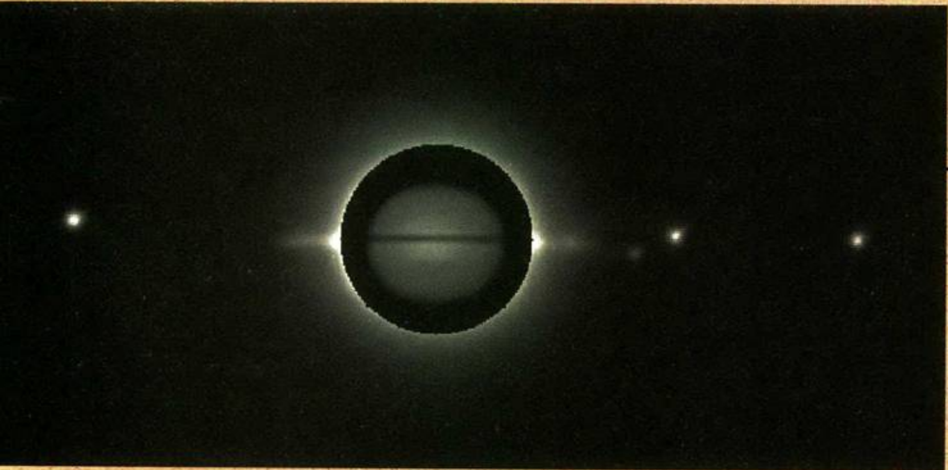
Eclipse over India

by Bob Yen (5.1-inch refractor at f/8, Ektar 25, 4-second exposure taken October 24, 1995, near Chattargarh, India)



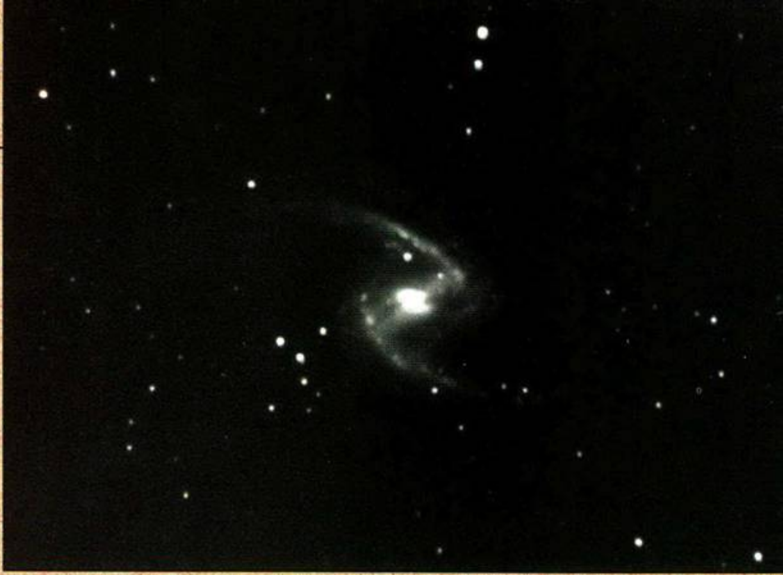
Gibbous Moon over Yosemite's Half Dome

by Paul Dalzell



Saturn with its Moons (l. to r.) Rhea, Mimas, Enceladus, Tethys, and Dione

by Donald G. Bruns
(10-inch SCT, Pictor 416 CCD camera, AO-2 adaptive optics system, infrared blocking filter, taken December 3, 1995)

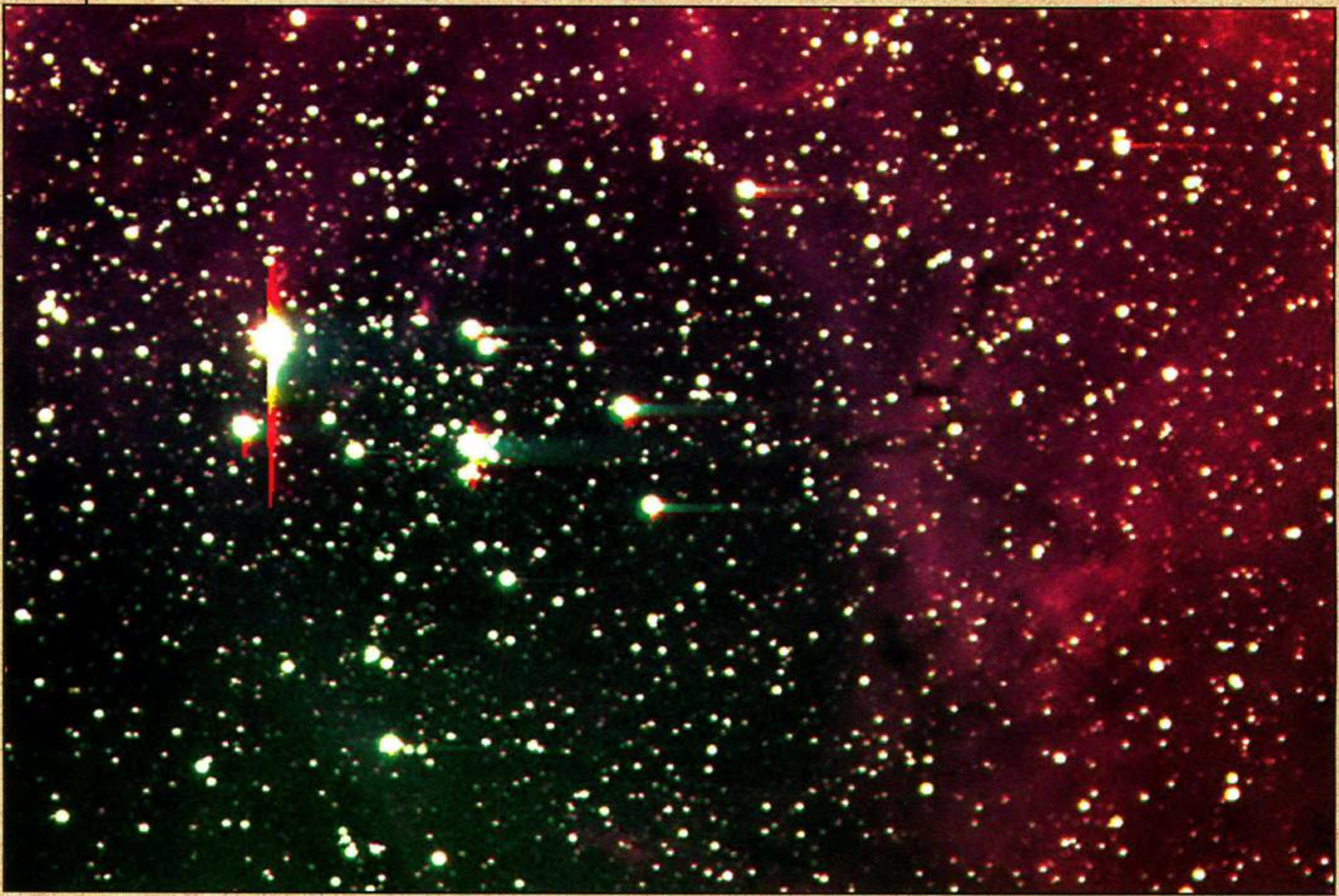


Barred Spiral Galaxy NGC 1365

by David Healy
(14-inch SCT at f/7, hypersensitized Tech Pan film, 60-minute exposure)

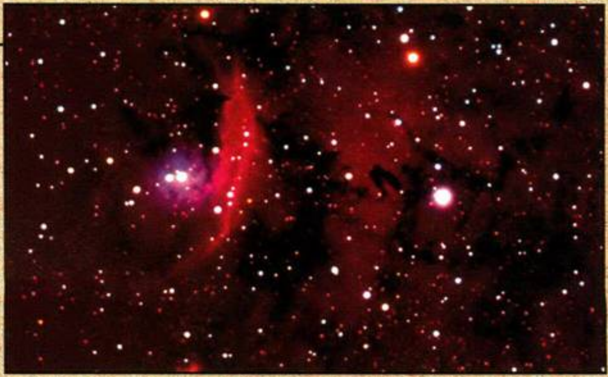
Core of the Rosette Nebula

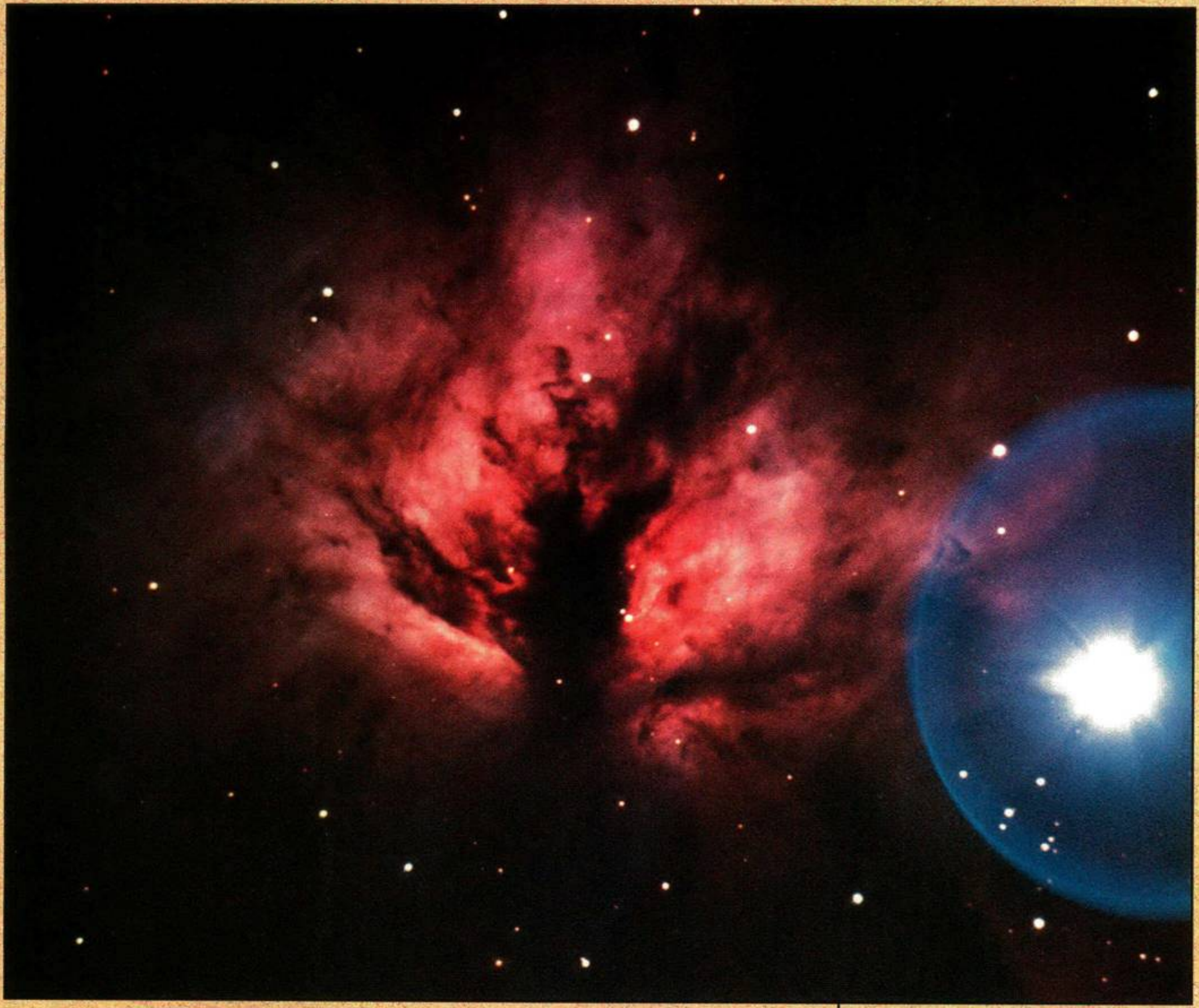
by Jack Newton
(7-inch refractor at f/6, Pictor 1616 CCD camera)



Dark Nebula Barnard 303 in Sagittarius

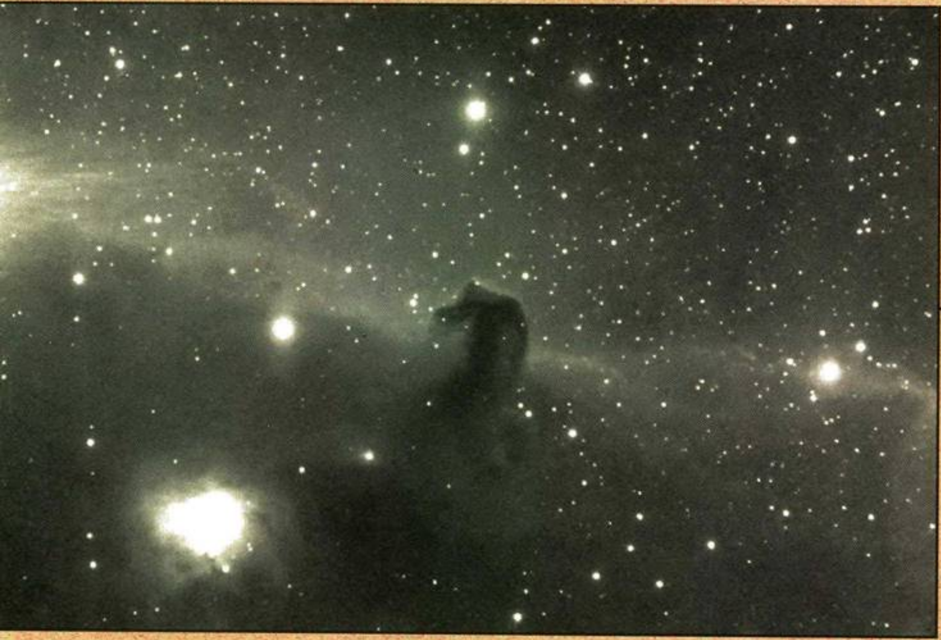
by James R. Foster
(14-inch SCT at f/7, hypersensitized Tech Pan film, composite of 218-minute blue, 183-minute red, and 132-minute green exposures)





Emission Nebula NGC 2024 in Orion

by Jason Ware
(16-inch SCT, hypersensitized Fuji HG 400 film, composite of two 16-minute exposures)



The Horsehead Nebula

by David Hanon
(7-inch refractor at f/5.5, ST-8 CCD camera, 20-minute exposure)

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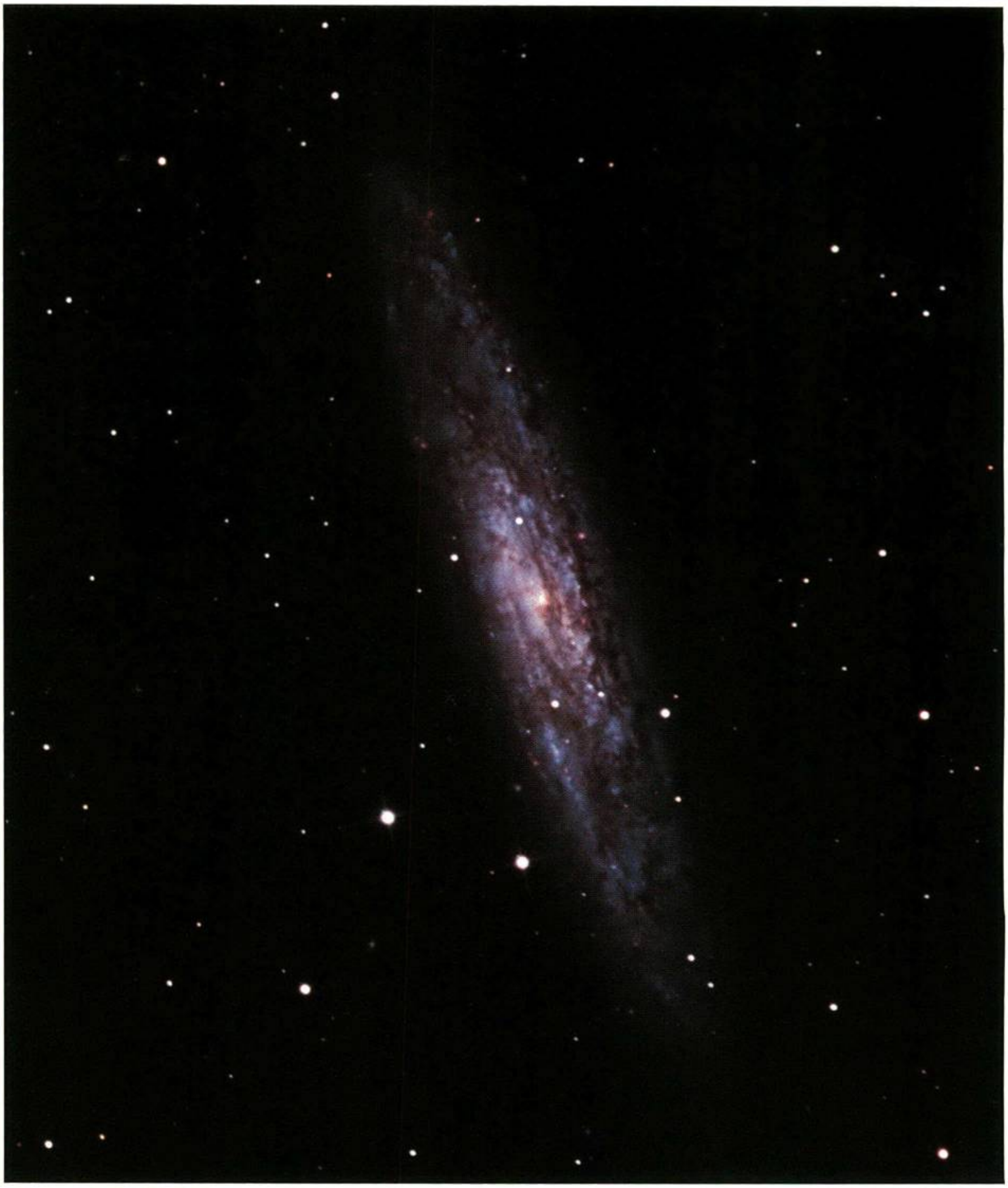

Spiral Galaxy NGC 253

by Andrew Peters
(20-inch f/5 reflector, hypersensitized Ektar 25 film, 150-minute exposure)

Magnificent clouds of dust are visible in this sharp portrait of the galaxy, which is one of the brightest in the southern sky. Australian Peters records deep-sky objects routinely with his large reflector, shooting extremely long exposures to capture the maximum faint detail. The sharpness of the dust in this image testifies to the quality of Peters' optics and the steadiness of the seeing.

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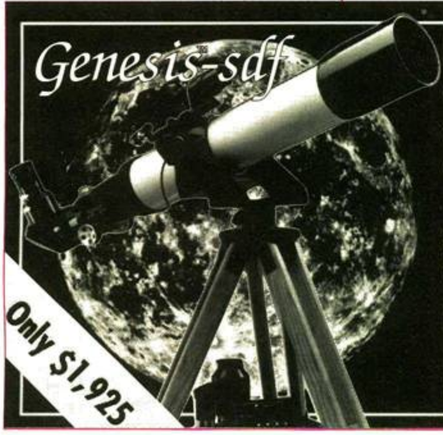

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